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A STUDY OF CAST-IRON BELL AND SPIGOT PIPE JOINTS BY THE PUBLIC WORKS DEPARTMENT OF THE CITY OF BOSTON.

BY CLARENCE GOLDSMITH.

[*Read April 15, 1914.*]

Cast-iron bell and spigot pipe has been used for the distribution of water in this country since early in the last century. The pipe of that period was cast in 9-ft. lengths without groove in the bell or bead on the spigot, and the joint was made up with lead in much the same way that it is to-day, but in some cases wooden staves were used instead of lead. This pipe was of comparatively small size, and the pressures to which it was subjected were in most cases less than 50 lb. In the course of time larger pipes were required and higher pressures utilized, and about the year 1850 the casting of grooves in the bells and beads on the spigots was begun.

These grooves gave the lead joint greater resistance against blowing out, and the bead facilitated the centering of the pipe, helped to hold the yarn, and contributed something to the holding power of the joint. Joints such as described have been adopted by the New England Water Works and American Water Works associations in their standard specifications, and are now universally used on cast-iron bell and spigot pipe laid for domestic distribution. Where bends, offsets, caps, plugs, blow-off valves, and hydrants are set on the line, it is frequently the practice to

tie them into the line with rods passed either through lugs cast on the pipe, gates and fittings, or through wrought-iron bands bolted around the pipe and fittings, or else to use set screws tapped through bosses cast on the bells and set down on to the spigot end.

In many cases, however, masonry abutments are built up against the line and fittings to resist the thrusts caused by irregularities in alignment and unbalanced pressure on caps and plugs. With the advent of larger sizes of pipe, operated under continually increasing pressures, steel pipe was, in the latter part of the nineteenth century, utilized to a large extent to meet the then more exacting requirements. The life of steel pipe has in many cases been short, due largely to lack of a durable protective coating, and in a measure to electrolytic action. Hence, when the question of a suitable pipe material came up in connection with the design of the earlier high-pressure fire service systems, there was considerable diversity of opinion. In 1897 the city of Buffalo decided to use steel pipe and laid a mile of such pipe with threaded joints, but additions in 1904 and 1906 to this installation were of cast iron. On the other hand, in 1898 the city of Boston used cast-iron pipe with a double groove in the bell for a high-pressure salt-water main of about one mile in length.

The first high-pressure fire service system covering any considerable area was installed in Philadelphia in 1903, and although the original designs contemplated the use of steel pipe, it was finally decided to use cast iron, and a flanged joint was designed for this special service. In 1909 it was decided to largely extend the system, and "Universal" cast-iron pipe was used for this work.

Cast-iron bell and spigot pipe has been used exclusively in the construction of the high-pressure fire service system of New York. The first pipe laid had double semi-circular grooves in the bell and on the spigot, and lugs or rings for wrought-iron bands were cast on all pipes and fittings set where the alignment of the pipe was changed, and on branches and dead-ends, thus providing for the tying of the line together with rods or bolts and nuts. In later installations the dimensions of the grooves were modified, but the practice of tying the lines together is still followed.

The city of San Francisco was the next city to undertake the construction of an extensive high-pressure distribution system. Most careful and complete investigations were made before cast iron was adopted as the material for the pipe lines. Because of the possible trying and exacting conditions which might be imposed upon the distribution system by an earthquake, T. W. Ransom, M. Am. Soc. M. E., and consulting engineer of the Board of Public Works, conducted an extended series of experiments, under the direction of City Engineer Marsden Manson, M. Am. Soc. C. E., on a large number of lead joints of varied design. The results of these experiments led to the development of a joint which was adopted for the work and is producing excellent results. The holding power of this lead joint, however, was not sufficient to permit dispensing with lugs and rods on dead-ends and on fittings out of alignment.

After careful study of the question of material for the pipes of the high-pressure distribution system, the city of Boston has adopted cast iron as unquestionably the best for the purpose. In designing pipe for such service the engineer is largely guided by the results of previous practice, and as the superiority of the joint adopted by the city of San Francisco had been demonstrated, both experimentally and practically, this type of joint was also adopted by the city of Boston. The use of lugs and rods was, however, considered open to criticism and serious objection, it being practically impossible to so adjust the rods in sets of four or six that each would take even an approximate share of its load. The rods, too, are subject to rapid deterioration when buried in earth of the kind found in the greater part of the area in which it is proposed to lay the pipe. The cost of each joint made up with lugs and rods exceeds that of a plain lead joint by approximately $20 for 20-in. pipe, $15 for 16-in., $7 for 12-in., and $4 for 8-in. These objections suggested the development of a more reliable and permanent method of holding the pipe line in place; but an even more serious objection presented itself to the use of the rod and lug construction in Boston. On account of the great congestion of existing underground structures it is of the utmost importance to economize in space by reducing the clearances to a minimum. The minimum clearances required for pipe with lugs are 35.5

in. for 20-in. pipe, 29.5 in. for 16-in., 24.25 in. for 12-in., and 18.75 in. for 8-in., while without lugs these clearances could be reduced 6, 5, 5, and 4.5 in. respectively. The advantages of the latter construction are, therefore, obvious.

Several methods of overcoming the difficulties which presented themselves were studied. First, the use of set screws in bosses cast on the bells was considered, but their holding power, when of reasonable size, would not be sufficient; and other objections were the difficulty of making them watertight, the expense of drilling and tapping the holes, and the work involved in adjusting the set screws.

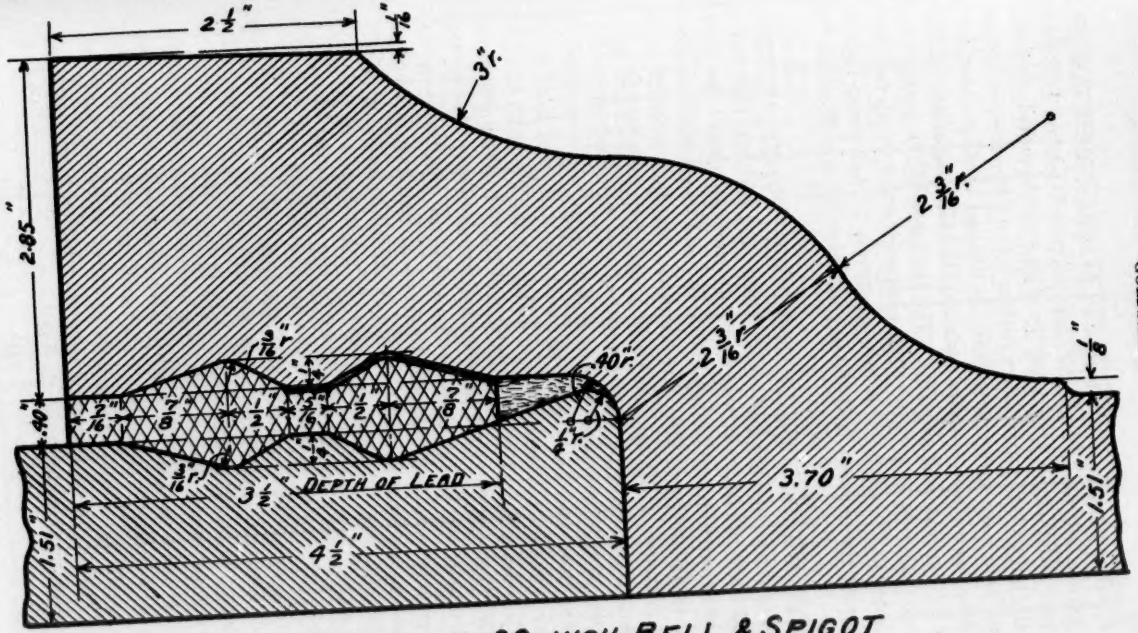
Interlocking wedges cast on the spigot and in the bells were next designed, but were not considered feasible, as the adjustment of the pipe in the ditch would be difficult, and there would be practically no flexibility of the line in case of settlement.

Experiments showed that the failure of double-groove joints of the design adopted was due to the flowing of the joint material rather than to the shearing of this material in the groove of the bell, as in the case of single-groove joints. It was clear, therefore, that the problem would be satisfactorily solved if a material could be found which would offer a much greater resistance to flowing than lead and could be poured and driven with moderate facility, and yet would not be so rigid as to prevent a sufficient movement in the joint to allow for settlement of the pipe line.

The materials available for an alloy of the character required are:

	Melting Point. Degrees Fahr.	Tensile Strength. Pounds.
Lead	600	1 600 to 2 400
Tin	450	3 500
Bismuth	500	6 400
Zinc	780	5 000 to 6 000
Antimony	1 150	13 000

To make the various joints for testing, 20-in. caps and plugs with double grooves of the design adopted cast in the bell and turned on the spigot were used. The depth of the bell in all cases was 4.5 in., and the joints were made up by centering the plug in the cap and yarning the joint until the face of the yarn, which was driven home with a hammer, was 3.5 in. from the face of the



SECTION OF 20-INCH BELL & SPIGOT

FIG. 1. TYPICAL LEAD JOINT FOR HIGH-PRESSURE PIPE.

bell. The plug was then tipped at an angle of about 45 degrees, a jointer adjusted, and the joint material poured. A round jointer provides for a sufficient lip of lead on the outside to permit of the joint's being flush when driven. If a flat jointer is used, its inner side next the joint should be beveled at 45 degrees for a distance away from the pipe equal to the thickness of the joint in order to provide sufficient lip. The thickness of the joints tested varied from 0.35 to 0.75 in. The caps were tapped with two 0.25-in. holes, one to receive the connection from a small pump capable of raising the pressure to 3 000 lb., the other to provide a vent for air.

In the first twelve tests, observations to determine the movement of the joint were made with a rule, and readings were taken to one sixteenth of an inch at two points on the plug. The pressure was raised in increments of 100 lb., and maintained constant for intervals of, generally, five minutes. In this series of tests two joints were made up with Omaha lead, four with 96 per cent. lead and 4 per cent. tin, one with 94 per cent. lead and 6 per cent. tin, two with 97 per cent. lead and 3 per cent. tin, two with 98 per cent. lead and 2 per cent. tin, and one with lead wool hand driven. The data obtained showed that an alloy of lead and tin made a joint which offered a greater resistance to the unbalanced pressure between the cap and plug than Omaha lead; that as the proportion of tin in the alloy is increased, the resistance of the joint is increased; that lead wool offers a greater resistance than Omaha lead, but not so great as any of the alloys used; that the joint did not reach its maximum power of resistance until the plug had moved some little distance out of the cap; that the alloy could be poured with about the same facility as lead, but that the driving of the joint required more time as the quantity of tin was increased; also that the joints when driven are watertight, but when a joint moved, a slight leakage was observed, which, however, disappeared before the joint had moved out far enough to develop its maximum strength. The method of making the observations, however, was not sufficiently refined to determine exactly when the joint attained its greatest strength, and the intervals during which pressures were maintained were not long enough to assure equilibrium of the joint.

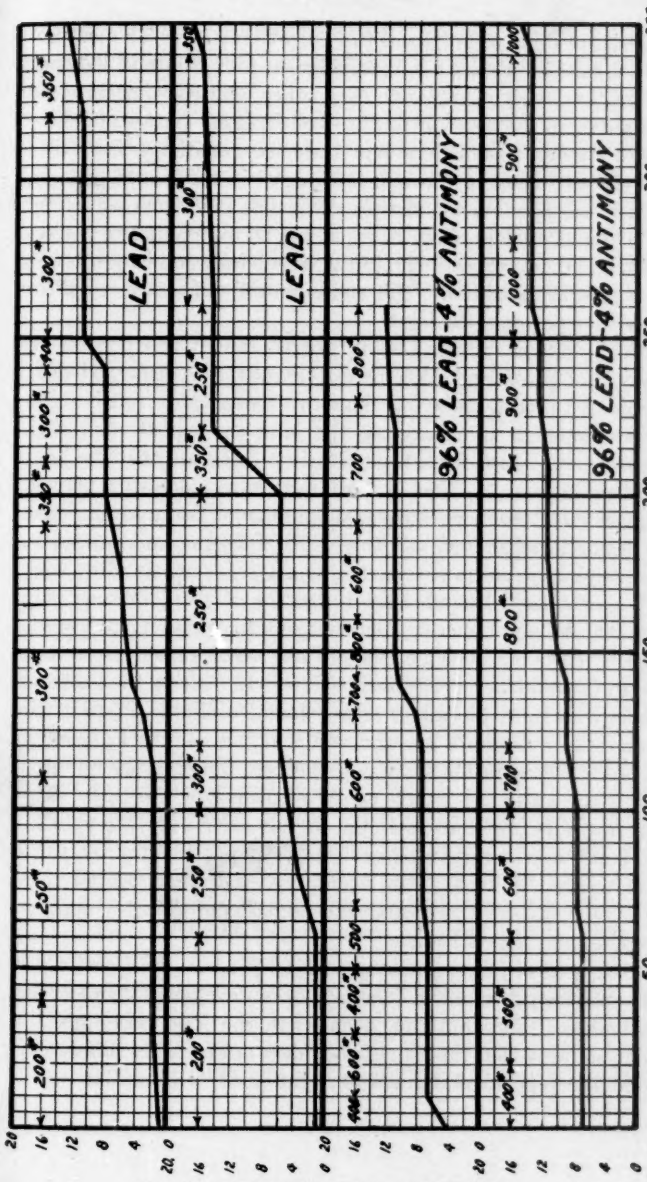


FIG. 2. JOINT MOVEMENT.

A series of three tests (Nos. 14 to 16) was run in which measurements to 0.01 in. were taken by dividers at four points at the ends of diameters at right angles to each other, and the time interval increased — in the last test to fifty-five minutes. In two of these tests an attempt was made to reproduce the condition which exists when the alignment of the pipe is changed in the trench, that is, in which one side is home and the other side is in one case 0.5 in. and in the other 1 in. from being home, corresponding to throws of 3 in. and 6 in., respectively, in the trench for a full length of the size of pipe being tested. This condition did not appear to affect the resistive power of the joint.

These preliminary tests having proved that it was possible to make a joint strong enough to permit tie rods to be dispensed with, a series of thirteen tests was next run under more reliable and accurate methods of measuring the joint movement, and with pressures maintained for a time sufficient to assure that the joint was in equilibrium. Three of these tests were made with Omaha lead, one with lead wool, three with an alloy of lead and tin, three with lead and antimony, and three with lead, tin, and antimony.

Although the results obtained with a 4 per cent. tin alloy were fairly satisfactory, the ultimate resistance of the joint was only about 500 lb., and the cost of tin is about 50 cents a pound, while antimony costs but 10 cents a pound and reduces much more than does tin the tendency of the lead to flow. In melting the lead and antimony to form the alloy, it was found desirable to melt the antimony in a separate pot and add it to the molten lead, for if they were melted in the same pot, the high temperature required to melt the antimony would cause a burning of the lead. The temperature required to melt the metals after they are synthetized is 900 fahr., or approximately halfway between the temperatures required to melt them separately, and when heated to a proper temperature for pouring, the oxidation of the alloy appears to be less than that of lead.

In the tests of joints made up with 96 per cent. lead and 4 per cent. antimony a number of small leaks developed between the pipe and the joint material, even when the joint was carefully driven, showing that the ring of alloy does not contract sufficiently around the pipe to make a watertight joint, whereas lead or a

lead-tin alloy assures watertightness. For this reason it was not practical to adopt this lead-antimony alloy, although its holding power was satisfactory.

The three tests made on the alloy composed of 96 per cent. lead, 2 per cent. antimony, and 2 per cent. tin showed that the alloy can be easily melted and poured, requires only about one third more time to drive than lead, and meets the requirements in other respects. This alloy was, therefore, adopted as the best material for the joint, and the joints thus made were found capable of resisting the unbalanced force developed by a pressure of 700

Nominal Diameter of Pipe. Inches.	Number of Rods.	Diameter of Rods. Inches.	Strength of Set of Rods in Pounds.	Resistance of Plain Lead Joint in Pounds.	Combined Strength of Lead Joint and Rods in Pounds.	Resistance of Lead-Antimony-Tin Joint in Pounds.	Maximum Allowable Pressure for Lead Joints in Pounds.	Maximum Allowable Pressure for Lead-Antimony-Tin Joint in Pounds.
8	4	1	52 800	47 400	100 200	133 100	540	1 550
12	4	1¼	85 700	68 700	154 400	192 900	390	1 100
16	6	1¼	128 600	89 800	218 400	252 300	320	900
20	6	1½	186 500	111 200	297 700	312 000	250	700
24	6	1¾	251 400	133 300	384 700	374 200	200	600

lb. per sq. in. on the 20-in. plug, amounting to 312 000 lb., which, since the circumference of the joint is 73.6 in., is equivalent to a resistance of 4 240 lb. per linear inch. The pressures which can be carried on plugs of other sizes may be readily calculated, and are shown in the preceding table, together with the calculated ultimate holding power of lead joints tied together with rods.

It will be seen from the foregoing table that the strength of the alloy joint is fully as great as the combined strength of the lead joint and rod for sizes of pipe up to and including 20 in. Although 20-in. pipe is to be the largest in the proposed system, 24 in. has been included in the table because pipe of this size has been used in some installations. A study of the plots of the various tests shows that the joint does not attain its maximum resistance to the internal pressure until the plug has moved out about 0.15 in. This is due to the fact that the alloy contracts in cooling, and as the

calking does not affect the material in the inner groove, this part of the joint does not offer its resistance until it is brought into bearing by the outward movement of the spigot end. During the progress of the several tests no leakage was observed until a pressure of 500 lb. per sq. in. was reached, and the leakage at this pressure, which was small, ceased before the joints had attained their ultimate strength.

In order to make a more complete and practical test of this joint material, a 20-in. line, consisting of a length of pipe, four $\frac{1}{16}$ bends, and a second length of pipe, was set up on blocking, and the ends were closed with a cap and plug. The joints were made up with yarn and an alloy composed of 96 per cent. lead, 2 per cent. antimony, and 2 per cent. tin, except that joint No. 6 was poured with a lead-tin alloy. All joints were driven with dog tools and finished with hand tools. The movement of the line while under pressure was recorded in the following manner:

A $\frac{1}{4}$-in. hole about one inch deep was drilled in the top of each of the seven bells, and a wooden pin, into which a sewing needle, pointing up, was inserted, was set in the hole. A stake was driven on either side of the pipe opposite each joint, so that a crosspiece extended over the pipe would be at right angles to the axis of the pipe. A small board upon which cross-section paper was mounted

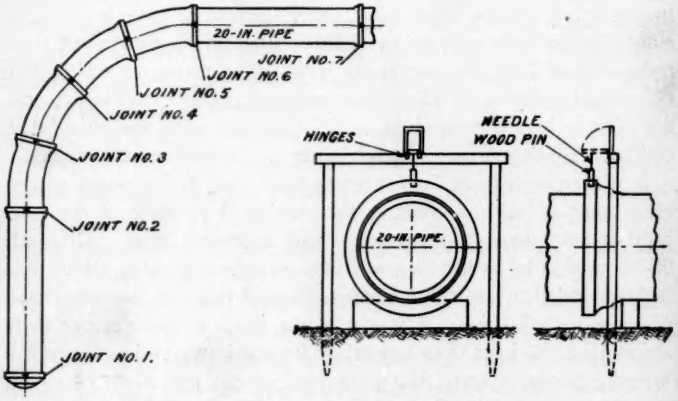


FIG. 3. EXPERIMENTAL 20-INCH LINE.

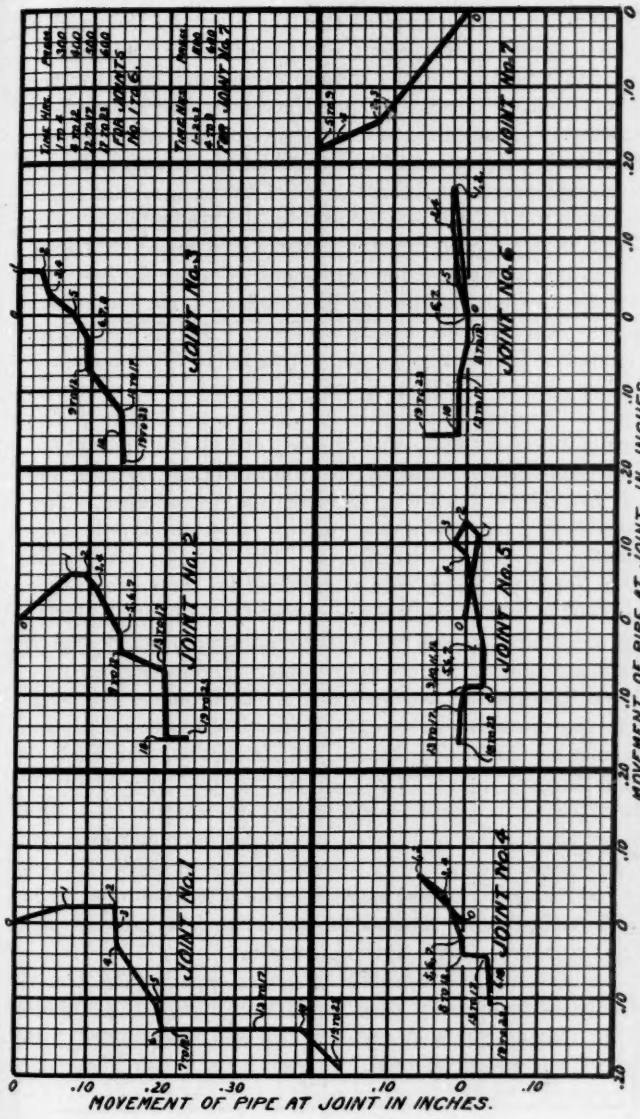

JOINT No.1
JOINT No.2
JOINT No.3
JOINT No.4
JOINT No.5
JOINT No.6
JOINT No.7
MOVEMENT OF PIPE AT JOINT IN INCHES.
MOVEMENT OF PIPE AT JOINT IN INCHES
MOVEMENT OF JOINTS IN 20 INCH PIPE LINE

FIG. 4.

was so hinged to each crosspiece that the needle in the wooden pin beneath it would just pierce the paper when the board was in its horizontal position. Holes were so drilled and tapped in the line that it could be filled and emptied, and provision was made to vent the line of air and to attach a pressure pump. After the line was filled with water a record was taken of the position of each bell by swinging down the boards on which the cross-section paper was mounted until a hole was pricked by the needle point. The pump was then attached and the pressure was raised to 300 lb. per sq. in. and maintained for four hours. During the last two hours of this period the line was in equilibrium and no leakage developed. The pressure was next raised to 400 lb. per sq. in. and maintained for eight hours, and during the last four hours the entire line was in equilibrium, and no leakage was apparent. The pressure was then raised to 500 lb. per sq. in., and joint No. 6, which had been made up with an alloy of lead and tin, did not come into equilibrium, but continued to draw out of the bell, and when it had drawn out 1.9 in. the test was discontinued. This joint was melted out and a new joint of lead-antimony-tin alloy was made, and the test continued. The pressure was again raised to 500 lb per sq. in. and maintained for three hours, then raised to 600 lb. per sq. in. and maintained for six hours. During the last five hours the pipe line was in equilibrium, but several of the joints sweated during the entire time. The leakage on joint No. 1 was the greatest, and equaled six fluid ounces per hour, which is equivalent to a leakage of one fourth of a gallon per linear foot of joint for twenty-four hours. An attempt was now made to raise the pressure to 700 lb. per sq. in., but the capacity of the pump, which had a displacement of only one seventh of a fluid ounce per stroke, was not sufficient. A second pump of larger capacity was secured, and with the two pumps in service a pressure of 700 lb. per sq. in. was maintained for fifteen minutes, when one of the bends burst. During this period the leakage increased but slightly, and no observations were taken.

The results obtained from the foregoing experiments showed that the lead-tin-antimony alloy would amply fulfill the requirements for making joints in cast-iron bell and spigot pipes with grooves of the design adopted. Inasmuch as it has frequently

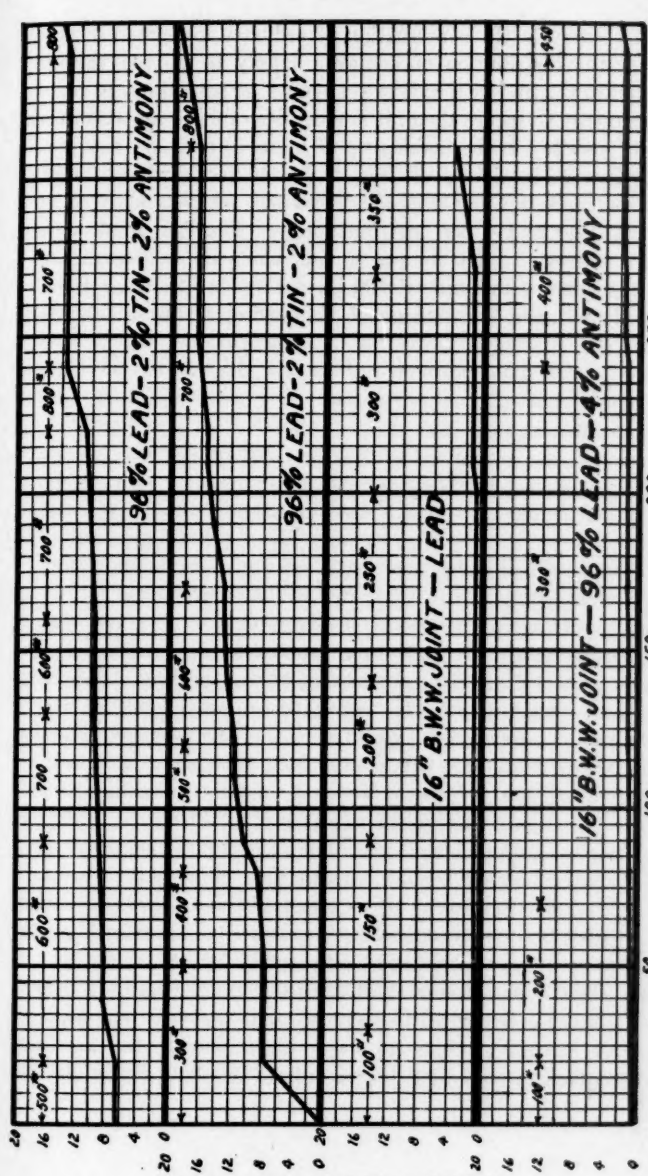

96% LEAD-2% TIN-2% ANTIMONY
96% LEAD-2% TIN-2% ANTIMONY
16" B.W.W. JOINT—LEAD
16" B.W.W. JOINT—96% LEAD-4% ANTIMONY
MOVEMENT IN HUNDREDTHS OF AN INCH.
TIME IN MINUTES

FIG. 5. JOINT MOVEMENT.

been necessary in the construction of ordinary low-pressure pipe lines for the distribution of domestic supply to tie the various fittings into the line with rods or set screws, or sometimes to build up abutments to secure them, it is most desirable to ascertain the effect of an alloy in the making up of joints in ordinary cast-iron pipe. Two 16-in. joints of Boston Water Works design were, therefore, made up, one with lead and one with an alloy of 96 per cent. lead and 4 per cent. antimony. The lead joint withstood a pressure of 300 lb. per sq. in., while the lead-antimony joint withstood a pressure of 400 lb. per sq. in., showing an increase of one third over and above the holding power of the lead joint.

MORTALITY RATES OF PHILADELPHIA IN RELATION TO THE WATER SUPPLY.

BY J. A. VOGLESON, CHIEF BUREAU HEALTH.

When any important sanitary measure is accomplished, we look to the mortality rates of the people affected, for the final value of the improvements. The filtration of the city water supply of Philadelphia was such a measure, and while the time which has elapsed since the last of the five filtration plants was put into service, in the latter part of 1911, is too short to permit complete analysis of the results from filtration, yet the marked changes which appeared in the typhoid rate, as district after district was added to the filtered water area, afford interesting data for examination.

Philadelphia was long scourged with typhoid fever, and the principal cause was finally attributed to the polluted rivers from which the city water supply is obtained. Thus, after many investigations, looking toward improving the water supply, the city began in 1900 active construction of the filtration works. Other sanitary measures to protect the water supply had been adopted in preceding years, — notably the acquisition of land now embraced in Fairmount Park, which was purchased from time to time for sites for pumping stations, reservoirs, and for protective purposes; the construction of the Schuylkill intercepting sewer, built to prevent city sewage from reaching the intakes of pumping stations on that river; and also the work of the State Health Department, which is progressing with increasing results toward sewage treatment for towns in the populous Schuylkill Valley.

Analysis of the mortality rates from 1862, which was the first year of complete record after the Registration Act of 1860, shows by decennial averages that the typhoid fever rate alternately fell and rose but did not again reach the high average of 79.9 per 100 000 which prevailed for the period 1862–70. It was not until

in 1909, when the city received 80 per cent. filtered water plus 14 per cent. sterilized raw water, that a decided break was made in the typhoid rate, although a reduction from the high rate of 72.4 for 1906 had been made in 1908, when the rate had dropped to 34.8, and the influence of the local reduction in districts receiving filtered water was reflected in the city rate. From that year the decline has been consistent to the 12.5 rate of 1912, and we may safely conclude that a large percentage of the cases of typhoid fever in Philadelphia was from water infection, and the reports of sanitarians which preceded the work of filtration have been amply verified.

On Fig 1, the total mortality and typhoid rates, the ratio of typhoid to total mortality, the percentage of filtered water in the city supply, and other data have been plotted to show their relations.

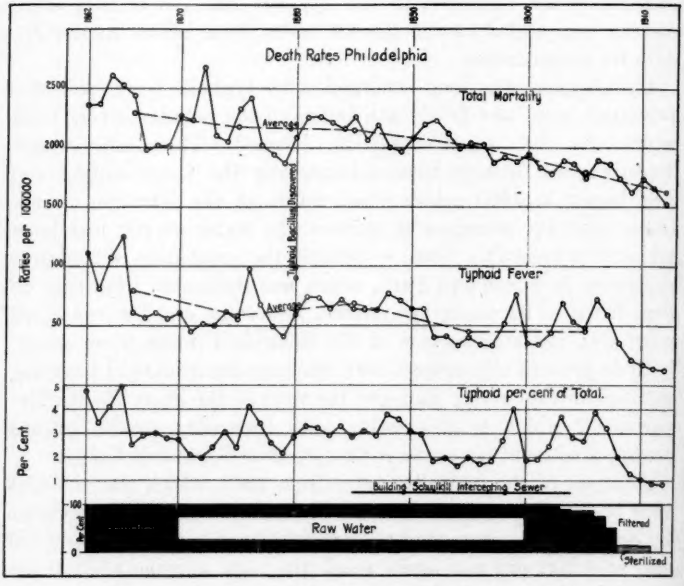


FIG. 1. DEATH-RATES IN PHILADELPHIA, 1862–1912.

The general downward trend of the total mortality rate since 1862 is shown on Fig. 1. The yearly fluctuations and the tendency to group in high and low levels are also shown. In all probability we may expect these fluctuations to continue in the future, yet we trust they will be in more modified form than in the past. In fact, the record for eight months of 1913 indicates that the mortality for this year will be higher than for 1912, which is the lowest year to this date.

TABLE NO. 1.

TOTAL DEATH-RATE AND TYPHOID DEATH-RATE BY DECADES, PHILADELPHIA

Period.	Mortality per 100 000. Total.	Typhoid.	Per Cent. Typhoid of Total.
*1862–70	2 291.2	79.9	3.49
1871–80	2 170.2	58.1	2.69
1881–90	2 142.9	68.5	3.19
1891–1900	2 018.7	44.6	2.17
1901–1910	1 792.2	45.2	2.57
1911	1 650	14.1	.85
1912	1 522	12.5	.82

* Nine years.

TABLE NO. 2.

CHANGE IN TOTAL AND TYPHOID MORTALITY RATES PER 100 000.

Period.	Total.	Per Cent. of Average. Previous Period.	Typhoid.	Per Cent. of Average. Previous Period.
1861–1871				
1870–1880	121.0 (dec.)	5.28	21.8 (dec.)	27.31
1871–1881				
1880–1890	27.3 (dec.)	1.26	10.4 (inc.)	17.91
1881–1891				
1890–1900	124.2 (dec.)	5.79	23.9 (dec.)	34.92
1891–1901				
1900–1910	226.5 (dec.)	11.24	0.6 (inc.)	1.35
1891				
1900–1911	368.7 (dec.)	18.29	30.5 (dec.)	68.41
1891				
1900–1912	496.7 (dec.)	24.58	32.1 (dec.)	72.00

The curve for typhoid fever consistently slopes downward with increased percentage of filtered water, and the effect of sterilized raw water is also clearly reflected. We can confidently predict that the low city rate of 12.5 per 100 000 will ultimately go still lower when all of the causes of typhoid fever have been brought under control, for we already have a large isolated section of the city which has a typhoid rate under 6 per 100 000.

TABLE NO. 3.

TOTAL MORTALITY AND TYPHOID RATES AND PER CENT. OF TYPHOID MORTALITY, PHILADELPHIA.

Year.	Rates per 100 000. Total Mortality.	Typhoid.	Per Cent. of Total.
1862	2 360	111.4	4.73
1863	2 373	81.2	3.42
1864	2 610	106.6	4.09
1865	2 525	124.9	4.95
1866	2 439	60.6	2.49
1867	1 976	57.2	2.89
1868	2 039	60.4	2.96
1869	2 027	56.4	2.78
1870	2 272	60.7	2.67
1871	2 231	45.3	2.05
1872	2 679	52.1	1.95
1873	2 097	50.1	2.39
1874	2 049	62.1	3.03
1875	2 323	55.2	2.37
1876	2 417	97.7	4.04
1877	2 013	68.2	3.38
1878	1 937	49.7	2.56
1879	1 865	41.4	2.22
1880	2 091	58.9	2.81
1881	2 248	74.3	3.31
1882	2 262	73.3	3.23
1883	2 213	63.8	2.88
1884	2 155	71.3	3.31
1885	2 253	64.2	2.85
1886	2 059	63.6	3.09
1887	2 185	62.5	2.86
1888	2 004	77.2	3.82
1889	1 974	70.7	3.58

TABLE NO. 3. — *Continued.*

Year.	Rates per 100 000 Total Mortality.	Typhoid.	Per Cent. of Total.
1890	2 076	63.6	3.06
1891	2 185	63.9	2.93
1892	2 225	40.3	1.81
1893	2 120	40.9	1.93
1894	1 990	32.5	1.63
1895	2 044	40.3	1.97
1896	2 017	33.8	1.68
1897	1 872	33.2	1.76
1898	1 918	51.5	2.69
1899	1 878	74.9	3.99
1900	1 938	34.7	1.79
1901	1 826	33.6	1.84
1902	1 770	43.6	2.46
1903	1 889	69.4	3.68
1904	1 856	52.8	2.85
1905	1 740	47.6	2.74
1906	1 886	72.4	3.87
1907	1 859	59.3	3.19
1908	1 744	34.8	1.99
1909	1 623	21.1	1.30
1910	1 729	17.4	1.05
1911	1 650	14.1	.85
1912	1 522	12.5	.82

TABLE NO. 4.

Per Cent. of Filtered Water in City Supply, Philadelphia.

Year.	Per Cent. Filtered.	Year.	Per Cent. Filtered.	Per Cent. Raw Water Sterilized.
1902	0	1907	25	...
1903	2.5	1908	48	...
1904	10.0	1909	86	14
1905	14.0	1910	86	14
1906	14.0	1911	87	13
1907	25.0	1912	100	...

The general mortality rate of Philadelphia has declined since the period 1862–70, and the first marked reduction occurs in the decade 1901–10, during which period the city was generally in-

creasing its filtered water districts. How much of this reduction is due to improved water supply and how much to other agencies for improving the public health is most difficult to answer. The general hygienic advance of the past fifteen years, and the increased activities in specially directed lines of health work, which will be referred to later, must not be lost sight of in reaching conclusions, especially as it is found that a large per cent. of the reduction in the total death-rate is due to the saving of lives of children under one year of age.

TABLE NO. 5.

PERCENTAGE OF TOTAL DEATHS OCCURRING BY AGE PERIOD, AND OF PERSONS LIVING IN THOSE PERIODS, PHILADELPHIA.

	PERCENTAGE OF TOTAL DEATHS.			PERCENTAGE OF TOTAL LIVING.		
Age Period.	In 1892.	In 1902.	In 1912.	In 1890.	In 1900.	In 1910.
Under 2.....	30.0	25.6	20.3	3.49	4.06	4.00
2–10.....	12.7	5.9	5.5	15.57	15.75	14.58
10–20.....	3.8	4.5	3.4	18.37	16.99	17.58
20–30.....	8.4	8.5	7.3	21.59	20.52	19.91
30–40.....	9.0	10.7	9.3	16.20	17.16	16.80
40–50.....	7.6	9.7	11.1	10.98	11.64	12.55
50–60.....	8.1	9.9	12.6	7.14	7.26	7.86
60–70.....	8.5	10.9	13.2	4.22	4.14	4.26
70–80.....	7.4	9.2	11.4	1.77	1.77	1.84
Over 80.....	4.5	5.1	5.9	.47	.43	.46
Unknown.....	...	...	...	.20	.28	.16

To show the trend of span of life in Philadelphia, Table No. 5 has been prepared, and in so far as these data show, the changes in distribution of deaths by age periods had their inception before the city had filtered water.

Thus, respectively in 1892, 1902, and 1912, 30.0, 25.6, and 20.3 per cent. of the deaths occurred in the age period under two years, with differences of 4.4 per cent. and 5.3 per cent. between years having raw water only and a year having raw water and one having filtered water respectively at ten-year intervals.

Mortality in Philadelphia was not registered under the International Classification of the Causes of Death until 1904, thus giving too brief an interval for a complete balancing of the changes in the total death-rate by disease groups. However, certain dis-

eases and the age-period under one year have been selected for examination as to the trend of their rates from 1890–1912, and are set forth in Table No. 6.

TABLE NO. 6.

TOTAL DEATH-RATE, DEATH-RATES FROM CERTAIN DISEASES, AND DEATH-RATES UNDER ONE YEAR OF AGE, PER 100 000 POPULATION, 1890–1912 INCLUSIVE, PHILADELPHIA.

Year.	Total Death-Rate.	Typhoid Fever.	Tuberculosis of Lungs.	Pneumonia.	Bronchitis.	Diarrhea and Enteritis.	Diphtheria and Croup.	Heart Disease.	Kidney Diseases.	Cancer.	Early Infancy.	Children under One Year of Age.
1890	2 076	63.6	264.5	192.5	50.0	160.6	90.0	133.4	70.6	51.3	223.8	50.5
1891	2 185	63.9	246.5	197.4	50.4	180.4	127.4	138.8	81.0	53.5	224.0	51.3
1892	2 225	40.3	247.8	202.3	56.6	187.8	156.3	145.0	79.9	52.1	226.4	52.1
1893	2 120	40.9	239.4	202.1	50.7	184.6	103.9	151.5	84.8	55.0	225.7	51.2
1894	1 990	32.5	221.5	188.0	42.2	171.3	122.5	133.0	83.2	51.7	212.9	48.0
1895	2 044	40.3	210.4	220.9	48.0	168.1	115.9	144.6	84.2	58.6	212.3	47.1
1896	2 017	33.8	211.5	227.5	44.4	169.0	97.2	145.1	87.2	56.9	198.3	43.3
1897	1 872	33.2	196.7	224.3	38.9	126.3	121.4	133.9	89.1	56.6	161.9	38.0
1898	1 918	51.5	208.8	200.0	35.1	158.0	93.0	145.3	90.9	54.0	168.2	40.6
1899	1 878	74.9	221.7	191.4	30.7	123.2	76.8	143.8	96.4	61.3	159.1	36.0
1900	1 938	34.7	210.0	228.7	34.2	134.1	79.3	145.4	89.3	62.6	175.4	39.0
1901	1 826	33.6	222.9	195.0	28.7	124.0	47.6	140.9	109.0	58.6	164.8	35.1
1902	1 770	43.6	211.0	220.5	28.3	114.1	37.4	147.0	103.6	63.7	155.7	34.3
1903	1 889	69.4	221.0	231.5	32.3	120.4	44.1	177.7	103.9	62.7	139.5	33.5
1904	1 856	52.8	221.0	210.9	34.7	128.2	38.4	172.0	144.2	73.6	100.4	35.9
1905	1 740	47.6	197.0	159.7	35.2	141.5	31.4	158.0	151.4	72.1	91.5	35.5
1906	1 886	72.4	215.0	183.7	44.0	165.3	37.1	162.0	156.7	76.7	87.0	39.9
1907	1 859	59.3	209.7	182.6	36.2	135.5	33.9	178.1	166.5	77.6	93.2	36.9
1908	1 744	34.8	200.2	173.0	34.8	130.4	32.5	165.9	154.9	80.6	84.2	35.2
1909	1 623	21.1	187.3	145.2	35.4	123.3	32.7	158.8	153.0	83.4	79.9	31.9
1910	1 729	17.4	184.8	182.7	34.4	163.6	31.7	177.2	150.2	83.0	71.8	33.7
1911	1 650	14.1	187.3	165.3	28.9	126.5	31.5	181.5	149.5	85.7	72.7	29.9
1912	1 522	12.5	165.2	136.5	26.3	101.6	24.2	198.1	149.4	87.8	87.9	25.9

Diarrhea and enteritis will be noted as having a downward trend from a high rate of 187.8 per 100 000 in 1892 to a lower rate of 114.1 in 1902, too early to be influenced by the improved water supply, and then followed by succeeding changes of rise and fall to take its last downward trend in 1910 to its lowest rate of 101.6

per 100 000 in 1912. It should be here noted that by far the largest percentage of deaths from these causes occur among infants, and that the peaks of this curve do not coincide with those of the curve of typhoid fever, with the exception of 1906.

In the Health Department we are inclined to consider that the changes in the rate have been influenced largely by work for improved milk supply and the campaign for the reduction of infant mortality, which has been carried on for some years, but with increased activity since 1906.

If the improved water supply caused the decrease in death-rate of children under one year of age from 1906 to 1912, what was responsible for the sharp decline from 1892 to 1897? Possibly children do not have the same diseases now that they did in the earlier period, and there may be a new series of illness now being overcome. We are, however, informed by physicians that babies are still subject to and have the same ailments, but that they are being better cared for. This decrease is in all probability largely due to improved milk supplies and to education in the care of infants.

The Health Department of Philadelphia has with a small corps of nurses, working in the congested districts, consistently reduced not only the death-rate among infants, but also there has followed a decrease in the death-rates from communicable diseases which was not shared in by wards adjacent to the ones in which this work was done. This happened not only in one year, but consistently followed in all the wards to which these nurses were transferred from year to year. Due credit for reduction of infant mortality must also be given to social and charitable organizations, working under private auspices, in ascribing the causes for the city reduction in infant mortality. Undoubtedly wholesome water is a factor, but proper food and housing and a host of other factors must not be overlooked.

Certain sections of the city have received a filtered water supply for longer periods than others, and in so far as the data will permit, examination will be made for results in those sections. It has previously been stated that a large percentage of the typhoid in Philadelphia was from water infection. This was first demonstrated when the Roxborough Filter Stations were put into service,

furnishing water to the twenty-first and twenty-second wards from 1903, and from these wards we have data for the longest period of comparison of raw and filtered water. This is a unit which changed in population from 72 229 in 1890 to 110 605 in 1912, in the meantime having one of these wards reduced in area. They occupy, in the main, high lying ground in the northwest part of the city and are principally residential wards, although they have also a mill district along the Schuylkill River. The variations in rates for these wards parallel quite strikingly the variations of the entire city.

TABLE NO. 7.

TOTAL DEATH-RATE AND DEATH-RATES FROM CERTAIN DISEASES PER 100 000 POPULATION, 1890–1912 INCLUSIVE, TWENTY-FIRST AND TWENTY-SECOND WARDS.

Year.	Total Death-Rate.	Typhoid Fever.	Tuberculosis of Lungs.	Pneumonia.	Bronchitis.	Diarrhea and Enteritis.	Diphtheria and Croup.	Heart Disease.	Kidney Diseases.	Cancer.
1890	1 626	69.4	227.8	148.6	34.7	155.5	33.3	116.7	58.3	61.1
1891	1 802	85.5	182.7	149.3	53.3	133.3	103.0	116.0	77.3	46.7
1892	1 730	48.0	210.4	137.7	37.7	139.0	90.9	110.4	72.7	49.3
1893	1 751	55.0	178.7	175.0	42.5	155.0	68.7	120.0	81.2	72.5
1894	1 464	19.5	165.8	96.3	24.4	132.9	98.8	91.5	70.7	51.2
1895	1 651	34.1	178.8	158.8	36.5	142.4	80.0	133.9	81.2	58.8
1896	1 653	33.3	158.3	173.6	34.5	116.1	42.5	156.3	107.9	55.2
1897	1 564	45.6	195.3	150.0	28.9	116.7	88.9	120.0	73.3	55.6
1898	1 599	31.5	165.2	122.8	18.5	116.3	80.4	151.1	94.6	57.6
1899	1 521	73.0	184.2	142.1	23.2	101.1	40.0	138.0	89.5	60.0
1900	1 573	35.1	162.2	196.9	30.9	105.0	34.0	108.2	115.6	60.8
1901	1 477	22.9	146.0	160.0	28.0	90.0	54.0	130.0	99.0	71.0
1902	1 530	22.1	159.3	190.7	38.4	107.0	52.3	147.7	95.3	61.6
1903	1 630	62.5	164.8	156.8	37.5	96.6	22.7	189.8	105.7	72.7
1904	1 645	29.7	170.0	194.6	30.8	96.7	24 2	180.2	116.5	82.4
1905	1 478	20.4	137.6	155.9	21.5	103.2	19.4	148.4	131.2	73.1
1906	1 471	25.1	170.8	130.2	38.5	115.7	19.8	150.0	116.7	72.9
1907	1 552	27.6	151.0	138.8	19.4	109.2	14.3	189.8	117.3	81.6
1908	1 559	30.7	159.4	124.7	26.7	103.0	10.9	181.2	134.7	86.1
1909	1 408	9.7	122.3	110.7	36.9	91.3	11.6	170.9	134.0	86.4
1910	1 303	15.1	113.2	132.1	28.3	112.3	21.7	180.2	126.4	111.3
1911	1 471	19.4	133.3	129.6	21.3	99.7	28.7	200.0	124.1	94.4
1912	1 323	35.1	103.0	103.0	27.9	85.6	18.2	196.4	103.6	79.3

The typhoid shows marked fluctuations, and while the reduction to 20.4 per 100 000 for 1905 was marked, yet in the year 1894 these wards had a rate of 19.5 per 100 000. This, we believe, is accounted for by reason of the large subsiding basins at the Roxborough Station having afforded a certain amount of protection in previous years. These wards have suffered from local milk epidemics and from broken mains, causing interruption in the service. Had it not been for such causes in 1910–11–12, we believe the low typhoid rate of 9.7 per 100 000 attained in 1909 would have been lowered in the subsequent years.

TABLE NO. 8.

TOTAL DEATH-RATE AND DEATH-RATES FROM CERTAIN DISEASES PER 100 000 POPULATION, 1890–1912 INCLUSIVE, WEST PHILADELPHIA.

Year.	Total Death-Rate.	Typhoid Fever.	Tuberculosis of Lungs.	Pneumonia.	Bronchitis.	Diarrhea and Enteritis.	Diphtheria and Croup.	Heart Disease.	Kidney Diseases.	Cancer.
1890	2 633	70.6	367.5	191.9	37.4	171.7	104.0	175.8	116.2	72.7
1891	2 612	53.8	339.4	220.0	33.6	153.8	82.7	160.6	169.2	73.1
1892	2 818	44.0	324.8	236.7	56.0	185.3	111.9	211.9	171.6	59.6
1893	2 544	33.4	313.1	226.3	35.1	176.3	88.6	175.4	157.9	62.3
1894	2 587	22.7	296.6	217.6	33.6	166.4	75.6	153.8	142.0	58.0
1895	2 435	35.5	297.7	174.2	35.5	151.6	73.4	168.5	150.8	60.5
1896	2 208	25.6	278.3	220.1	24.8	125.6	69.8	165.1	169.0	58.9
1897	2 029	40.4	262.7	227.6	32.8	117.2	59.0	162.7	191.0	65.7
1898	2 104	49.1	291.4	174.8	36.7	161.9	74.8	164.0	172.7	71.9
1899	2 205	78.8	340.4	179.0	28.0	107.0	88.2	194.4	193.7	76.2
1900	2 670	39.9	405.4	241.2	28.4	137.2	68.2	240.5	229.7	99.8
1901	2 718	53.1	430.4	245.6	29.7	131.0	53.2	195.6	367.7	99.4
1902	2 480	79.6	390.5	242.3	25.0	108.3	20.8	193.4	316.7	108.3
1903	2 509	88.1	379.2	263.5	25.3	101.7	37.1	262.9	256.7	94.9
1904	2 441	78.6	412.7	231.4	26.6	126.1	26.6	231.4	243.6	102.0
1905	2 263	33.8	348.5	167.2	27.3	145.8	21.7	135.9	247.5	101.0
1906	2 090	45.2	300.0	193.7	36.5	158.7	33.7	173.6	182.1	98.1
1907	1 801	28.9	172.5	169.3	30.7	130.7	36.7	169.7	164.2	98.2
1908	1 695	25.4	194.3	143.0	22.4	131.6	32.5	173.2	150.0	95.6
1909	1 510	14.7	190.8	127.7	29.4	104.2	25.2	162.2	148.3	100.0
1910	1 822	11.7	190.3	186.7	26.6	177.0	24.2	187.9	166.5	96.0
1911	1 678	9.3	179.5	164.7	22.1	127.1	24.0	189.9	158.1	105.8
1912	1 561	5.9	165.7	142.2	20.9	130.6	19.8	207.8	147.4	89.9

The figures for the other diseases show the general characteristics previously explained in detail for the city as a whole.

A second isolated section for study is afforded in West Philadelphia, which has had all of its city water supply filtered since 1906 and where the typhoid rate has dropped to 5.9 per 100 000 in 1912. This section of the city is located west of the Schuylkill River, from which its water supply is taken, and has increased in population from 99 102 in 1896 to 267 840 in 1912, almost threefold It is largely a residential section, and its water supply is entirely separate from the remainder of the city. Numerous asylums, hospitals, homes for the aged, etc., are located in West Philadelphia, and the mortality statistics are strongly influenced by this institutional factor, which is included in the rates computed.

When it is considered that the water supply of West Philadelphia is taken from a grossly polluted stream, and the people, in large part, pass daily into a district that has not had as good water, and that it has had its typhoid rate reduced from a high rate of 88.1 per 100 000 in 1903 to a rate of 5.9 per 100 000 in 1912, the capability of filtration works is at once apparent.

The time elapsed since the entire city water supply has been filtered is too short for any suggestion to be made as to what ratio the Mills-Reineke phenomenon, — as expressed by the Hazen theorem,* where one death from typhoid fever has been avoided by the use of better water, a certain number of deaths, probably two or three, from other causes have been avoided, — will take for this city.

The total death-rate has on the average declined since the period 1862–70. The decline more than doubled during the decade 1901–1910, when the water supply was being improved, during which period the typhoid rate rose slightly. The total death-rate has since continued to decline, and the Health Department is striving to make it go still lower, but as to how much of the decrease in total mortality can be attributed to the better water supply, under the complex conditions which influence the death-rate in this city of 1 600 000 people, the writer frankly states he will not undertake to express an opinion. This is stated in no spirit of

* Sedgwick and McNutt, *Journal of Infectious Diseases*, Vol. 7, No. 4.

TABLE NO. 9.

CHANGES IN TOTAL AND TYPHOID MORTALITY RATES PER 100 000 POPULATION.

Period.	Total.	Decreases.	Typhoid.	Decreases.	Total less Typhoid.	Decrease from Previous Decade.	
			Philadelphia.				
1862–70	2 291.2	....	79.9	....	2 211.3	....	
1871–80	2 170.2	121.0	58.1	21.8	2 112.1	199.2	
1881–90	2 142.9	27.3	68.5	*10.4	2 074.4	37.7	
1891–00	2 018.7	24.2	44.6	23.9	1 974.1	100.1	
1901–10	1 792.2	226.5	45.2	* .6	1 747.0	227.1	Changing water supply.
1891/1900–1911	1 650.0	368.7	14.1	31.1	1 635.9	338.2	Compared with '91–'00.
1891/1900–1912	1 522.0	496.7	12.5	32.7	1 509.5	464.6	Compared with '91–'00.
			West Philadelphia.				
1892–97	2 463.8	....	33.6	....	2 430.2	....	Six-year period.
1898–03	2 447.7	16.1	64.8	431.2	2 382.9	47.3	Six-year period.
1904–06	2 264.7	199.1	52.5	12.3	2 212.2	170.7	Changing water supply.
1907–12	1 677.8	786.0	15.9	36.6	1 661.9	721.0	Compared with '98–'03.
1912	1 561.0	886.7	5.9	46.6	1 555.1	827.8	Compared with '98–'03.
			Twenty-First and Twenty-Second Wards.				
1894–02	1 559.0	....	35.2	....	1 523.8	....	Nine-year period.
1903	1 630.0	*71	62.5	*27.3	1 567.5	23.7	Changing water supply.
1904–12	1 490.0	69	23.6	11.6	1 466.4	56.4	Compared with '94–'02.
1912	1 323.0	230	35.1	.1	1 287.9	235.9	Compared with '94–'02.

* Increase.

criticism or attempt to dispute the Mills-Reineke phenomenon, and the facts here presented have been given only to show the very great difficulty in demonstrating it for Philadelphia.

West Philadelphia in one case shows a great decline in total mortality, and in practically all of the selected diseases, in its brief period of filtered water, but mortality rates of many diseases have been profoundly influenced by its institutional factor. Likewise, the twenty-first and twenty-second wards have experienced a decreased mortality rate with a fluctuating typhoid rate, due in large part, with but one exception, to other causes than water supply.

It is confidently expected that the death-rate of Philadelphia will be still further reduced from its too high level. It is believed that the water supply will be a factor in effecting that reduction, for the hygienic value of a good water supply is unquestioned. Even suspicion of the water has both a physiological and psychological effect: the former in that sufficient water will not be used for physiological needs; the latter in that the element of fear will exert a depressing effect and add to the harm done by the use of too little water.

It is believed that the facts set forth show that a large percentage of Philadelphia typhoid was from water infection and that a great reduction in the typhoid rate must be largely attributed to the filtration and improvement of the water supply. As to the other effects of the changed supply, we can safely await the outcome of the future.

PROPER CHARGE FOR FIRE PROTECTION SERVICE.

TOPICAL DISCUSSION.*

[*June, 1914.*]

MR. W. E. MILLER† (*by letter*). It would doubtless be impossible for anyone to successfully maintain that fire protection service should be furnished entirely free of special charge as though covered wholly by the public hydrant rentals or other earnings. Courts have held, and will probably continue to hold, that it is a special and valuable service for which the utility is entitled to compensation, — that is, if the utility demands it. The question is, How much can utilities reasonably and properly demand as annual rates for connections of specific sizes? In other words, How valuable is the service?

It is reported that a large number of the water plants of this country, including several privately owned works, are voluntarily furnishing such service free of special charge, apparently on the grounds that such service is of mutual benefit and that it is fire protection service and as such it is covered in the public hydrant rentals. Numerous other plants, both publicly and privately owned, are making a small, merely nominal annual service charge. Others are advocating rates that are quite substantial, if not high.

Some statistical information of interest in this connection, compiled from 55 answers received in reply to a circular letter sent by him to 75 representative city water departments and water companies scattered over the country, was presented in a paper by F. A. Raymond at the Denver convention of the International Association of Fire Engineers, held in 1912. In summarizing Mr. Raymond says:

"Briefly, these figures show that four fifths of the city works and one third to one half of the private works make no charge or only a nominal charge for fire connections; the rest charge all the way from $22.50 to $120 for various 6-in. connections, the com-

* Continued from page 67.

† Division Engineer, Railroad Commission of Wisconsin.

panies generally charging the higher figures. Such rates as $105 and $120, which two western cities charge for connections used only for fire purposes, together with the expense of installation, interest, etc., will go far toward balancing any saving in rates the ordinary property owner would make by installing standpipes or sprinklers, and in effect act to penalize him for reducing his hazard and the exposure to his neighbors. Of course the taxpayer must also pay his share of the general city fire protection."

The question becomes involved in every water-works rate case wherein the utility furnishes, or stands ready to furnish, service of this character. It also has to be met and settled irrespective of the rates for other classes of service when a water works begins to take on consumers in this class and circumstances do not call for a readjustment in the entire rate schedule.

The settlement of the question involves the determination of the principles on which the value of the service is to be measured. Some have advocated the establishment of rates for public water service to private fire lines on the basis of the probable cost to the owners of protected premises of supplying their own water service. Such an idea raises the question as to whether those same parties would or would not attempt, or expect to be able, to establish rates for each and every consumer in all classes on the same basis. The idea is certainly not in accord with the soundest principles of public utility rate-making or public policy.

Others have advocated the establishment of charges for private fire service on the basis of the saving produced to the owner of protected premises in his cost of insurance. Would it not be just as logical and reasonable to fix rates for each and every private consumer on the basis of the same proportion of the savings that might be shown to be obtained by him in one way or another? The application of the idea is very much in doubt.

Courts and commissions having jurisdiction in making rates for public utilities seem to have universally held that rate-making consists of a fair and equitable distribution of the total cost of furnishing the service rendered by the plant, including in such total cost the maintenance and depreciation of the property and a fair and equitable return to the investors on the value thereof.

This principle brings the question of proper charges for private

fire protection service down to the determination of the proportions of the various items in the total expense which can logically be apportioned to and charged against this particular class of service.

The primary apportionment to be made seems to be generally recognized as being between the public (or municipal hydrant) service on one hand, and the private (or all other) service on the other.

The municipal hydrant service includes the public fire protection furnished by the water works in conjunction with the services of the fire department. This form of fire protection is quite generally if not universally recognized as less efficient than automatic sprinkler systems, as is strongly evidenced by the difference in insurance rates for sprinklered and unsprinklered risks.

If a water works has the facilities for coping with fires in its territory in the ordinary and less efficient manner, that is, through hydrants, it certainly has the necessary facilities for fire-fighting through the more efficient apparatus except for the physical connections to the private apparatus. These connections involve an investment of money, either by the utility or by the owners of the premises served. They also require supervision and watching. If they be unmetered the utility is, as has been so widely shown by experience, in danger of suffering through the misuse and abuse of the service; that is, through the secret use of large quantities of water for purposes other than quenching fires.

If private fire service connections be unmetered, they require close inspections and tests. If metered, they involve meter expenses and a meter reading cost.

The writer's view is that the public hydrant service should, in general, bear the fire protection portion of all expenses of the plant up to the points of beginning of the private fire-service connections, for the reason that if the water supply and pump and pipe line capacities are adequate for hydrant service they are certainly adequate for a more efficient method of fire fighting.

It has been assumed, in the foregoing statements, that the private fire-service connections are equipped with reliable means for at all times maintaining control over the flow of water through them. Experience has shown that such control is not secured by

merely installing an ordinary manually operated gate valve on the line in such proximity to the building protected that flames from the building or a falling wall render the valve inaccessible at a critical moment.

Why not profit by the sad and costly experiences of the past and provide against loss of control of the water supply to and through such connections? Charging large annual rates or fees for inadequately protected service connections will not do it. The service charges to be made are more properly commensurate with the facilities provided than with the dangers existing through lack of proper provision against them. This protection against the dangers can be provided in more ways than one.

Nothing said herein should be understood as implying a belief on the part of the writer in depriving any utility of any just revenue, for such idea is farthest from his intent. It is merely a question as to how any given amount of total revenue should be distributed over all the service and consumers, public and private. It has seemed impossible to find any but a purely arbitrary basis upon which to apportion to private fire-protection services any of the investment charges involved by the pumping plant or system of mains which, so far as any fire-protection service whatever is concerned, is necessary for the hydrant service irrespective of whether the more efficient sprinkler service is furnished or not. So far as operating expenses are concerned, the charges against private fire protection should be limited to the inspection and maintenance costs involved by these connections and to output charges for water used through them for purposes other than fire fighting. The amount of water so used can and should be known from a meter on each line. The capital or investment charges included in rates for this class of service should be limited to the utility's investment in the connections.

In the writer's judgment the proper rates for private fire-protection service are relatively low as compared with certain rates that have been advocated.

SOME PROBLEMS IN THE DESIGN OF SMALL WATER-WORKS SYSTEMS.

BY WILLIAM S. JOHNSON.

[*Read March 11, 1914.*]

It is the lot of most engineers and water-works superintendents to have to deal almost exclusively with small things — to have to solve innumerable petty problems — and solve them, generally, without the assistance of books.

Most of the available printed information relates to the large things in engineering. The engineer or superintendent reads with great interest the accounts of the New York water supply, the Wachusett Reservoir, or the Panama Canal, and, perhaps dreams of similar accomplishments, but he is apt to do the small things which are likely to constitute his lifework in the way he has always done them or in the way in which he has seen some one else do them. If, perchance, he makes some improvement in the methods, he is likely to keep it to himself, thinking it, perhaps, too small to interest the Water Works Association or the readers of engineering periodicals, who have been surfeited with the great engineering feats; and the next man who has the same problem to solve has to solve it independently.

One does not realize the comparative dearth of reliable information relating to small things, such things as are likely to come up in the average engineer's practice, until he begins to search for it in the books. He will find details of the greatest dams which have been constructed and of the great aqueducts, but very little that will help him in designing a twenty-foot dam or a system of small water pipes. Page after page is devoted to the things which not one engineer in one thousand ever has an opportunity to design, but with little or no space for that which every engineer is almost certain at some time to want to know. They may be things which can be worked out without assistance, but the experience of others is likely to save many mistakes and is almost certain to

save somebody considerable expense. There is as much opportunity for good engineering in the construction of a small water-works system as in the construction of the Panama Canal. That is, the problems are as numerous and as complicated, and the pocketbook of the man who helps pay the bills for the small water-works system will be more affected by the good or poor engineering in such a system than that of the individual who helps pay the bills for the Panama Canal.

The same can be said of the management. A good superintendent can do more to reduce the water rates in a town of three thousand than can the superintendent in a large city. The great trouble is that there is no glory in cutting off five hundred dollars from the cost of construction of the fifty-thousand-dollar water-works system or in saving two hundred dollars in maintenance by good management, even though the water rates may be kept down thereby, while in the working out of some problem in a large undertaking in which there is great public interest, there is much glory even though the proportionate saving may be less than in the small system.

Not only does the engineer or the superintendent of a small system get no glory, but he is likely to get no adequate compensation. The difference in salary between the water-works superintendent under whom the expenses of the department are $10 000 and the one who reduces them to $8 000 is not generally noticeable, and the difference in the compensation between the engineer who plans works for $60 000 and the one who gets the same results for $50 000 is likely to be in favor of the former, for the smaller the total cost, the less the fee of the engineer is likely to be.

In the state of Massachusetts there are 215 water-supply systems, and of these 152 were installed before the population of the towns they supply was five thousand, and 111, or more than half, are now still supplying towns of less than five thousand. In fact, the opportunity seldom comes to design a complete system of works for a large community, the larger systems being extensions of the systems designed for the small town. As there are only four towns in Massachusetts having a population of more than three thousand which remain unsupplied with water, it is likely that, in this state at least, the problems arising in small systems will

be more numerous than the problems connected with the larger systems, although perhaps not so interesting to any but those immediately affected.

The importance of the small water-works problems is indicated in the following table giving the number of towns of given populations in Massachusetts having and not having public-water supplies.

Population (1910.)	Number of Places Having Public Water Supplies.	Number of Places *Not* Having Public Water Supplies.
Under 1 000	6	80
1 000–1 499	21	29
1 500–1 999	13	20
2 000–2 499	21	12
2 500–2 999	12	2
3 000–3 499	8	1
3 500–3 999	5	2
4 000–4 499	7	1
4 500–4 999	10	..
Above 5 000	103	..
Total	206	147

In my practice it has been my lot to put in a number of small water-works plants, and it has surprised me to see how easy it is to save ten per cent. of the cost of construction by a thorough study of the problem. I have also found that many problems over which I have worked have been solved by others who have kept the results to themselves, not because of unwillingness to part with the information, but because the matter seemed too small to be of general interest. It is with a view of encouraging the discussion of the problems connected with small water-works installations, as well as to give a few of the results of my own experience, that this paper is presented. The problems are numerous, and it is possible to discuss here only a few of them, selecting those which are likely to have the greatest influence on the cost of the plant.

TIME FOR WHICH WORKS SHOULD BE BUILT.

The first problem which presents itself in designing a water-works system is the determination of the size of the plant to be

constructed, and this depends, in the first place, upon the time for which the works should be built. A distinction should be made between the time for which works should be built and the time for which they should be designed.

The works should be designed for a long time in the future. That is, the probable requirements of the future should be carefully studied and the means of fulfilling these requirements considered and in a rough way determined. But the design should provide for as little immediate construction as is possible except where the cost of extensions or increased capacity will be much more than the cost of doing the work in the beginning.

There is no doubt that many water-supply systems have been constructed to serve too long a period, and that money has been wasted in this way.

Many a water-works superintendent has portions of his plant which he wishes had been designed for a shorter period, so that it might now be rebuilt to better serve the present requirements.

To build works for a long time in the future assumes a power of prophecy which most of us do not possess. In the first place, it is beyond the power of man to foretell what is going to happen to any community and especially to the small town. A hitherto prosperous community may no longer prosper, or the population may advance by leaps and bounds, making the plant designed for a slow-growing town out of date in a short time.

To illustrate this, Fig. 1 has been prepared, which shows graphically what has happened in several places where water supplies have been introduced. The diagram shows the population for each census period before and after the introduction of water. The information at the left of the heavy line was available at the time the works were introduced, and in no case was there anything in the past growth to indicate that the future was to be what it actually was, as is shown to the right of the heavy line. Of course these are exceptional cases, for in the great majority of towns the past growth and the growth of other towns similarly situated give a fair indication of what may be expected in the future.

Besides the uncertainty as to what may happen to the town as a whole, there is the uncertainty as to the direction which growth

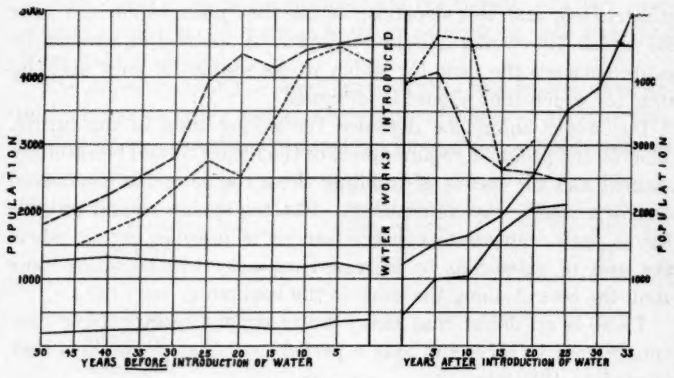


FIG. 1.

may take within the town. There are numerous cases where what promised to be the center of the business district of the town has become merely a suburb of another unthought-of center.

Advancements in the art of water-supply engineering are very rapid, and these are likely to make certain parts of the plant obsolete within a comparatively few years, so that they must be abandoned, or ought to be abandoned.

The rapid changes in the requirements of the public which uses the water is another factor making it unwise to build for too long a time. The standards of purity of twenty years ago do not at all meet the present requirements for clear and colorless as well as safe water. Many a supply which was considered good a few years ago is now considered unfit for use. A distributing reservoir which gave a very satisfactory pressure is now supplanted by a higher reservoir to meet the modern requirements for fire protection.

The changes which may be necessary or desirable in the sources of supply are indicated by the fact that of 163 sources of public supply in use in Massachusetts twenty years ago, 37 have been abandoned. Some of these were abandoned for larger sources, but most of them because the supply was unsatisfactory for some other reason.

Another reason why works should not be constructed for too

long a time in the future, is that it is wrong to call upon one generation to pay for the plant which another generation is to use, and especially as the next generation is likely to be much better served by modern, up-to-date works constructed to meet the requirements that then exist.

It is obvious that no part of the plant should be built to serve a longer period than the life of that particular portion, and this, in the more perishable parts of the plant, may well form one limit, but most of the plant has a duration of life well beyond the period for which the works should be built.

What has been said concerning the desirability of planning for the future but building for the present applies particularly to the source of supply. In developing the sources of supply, it certainly is not necessary or wise to develop in the beginning works which will supply the maximum requirements under the most unfavorable conditions for many years in the future.

The putting in of a water-works plant is not like building a bridge, for in the latter case the structure must be built to take the greatest load which it may have to carry, and this load may come at any time. If the bridge fails, the results are disastrous. In developing a water supply the greatest load will come at some time in the future when the consumption has greatly increased and when an unusually dry year occurs. When it comes, however, it will give sufficient warning so that extensions may be made to meet the emergency, and in case of necessity restrictions may be placed on the use of the water, curtailing the amount used for unnecessary purposes. While such restrictions are not desirable, it is obviously better to plan on resorting to them in great emergencies than to expend large sums of money in preparing for such emergencies which may never arise during the life of the works.

We are told that the greatest drought, of which we have any record, occurred about ninety years ago, and if all the water works which have been constructed since that time were built to supply water during such a drought there would have been an absolute waste of many dollars, for it has never occurred again.

Many times considerable sums can be saved in the construction of water works by developing sources of supply which are

known to be inadequate in a very dry season, with plans prepared, however, for the installation of an additional supply when required. A recent instance of this is the construction of the works of the Deerfield Fire District. A well was constructed from which a gravity supply could be obtained, adequate during most of the year but very limited in quantity during a dry season. Advantage was taken of the fact that during the first years of the works the consumption would be small and also of the chances that a dry season might not occur, and the auxiliary pumping supply which had been planned was omitted. The well alone supplied the town for two or three years before it was necessary to construct the auxiliary pumping station by which the gravity supply was to be supplemented, and had the exceptionally dry years not then come, the time would have been much longer. This auxiliary supply was put in when needed at no greater cost than if it had been installed in the beginning, and the interest on the investment for three years was saved.

In a recent report to the city of North Adams, Prof. G. F. Swain well expresses this idea. "In seeking a source of water supply, therefore, the aim should be to secure a source which is adequate for the near future and which is sufficiently flexible and possessed of such potentialities that, as the demand increases, the system may be extended from time to time. It will manifestly conduce to economy if the system can be extended as the need is felt, rather than if the distant future has to be provided for at the outset."

Experience indicates that the time for which the durable portions of small water-works plants, except the source of supply, should be constructed is about thirty years, the time ordinarily allowed for the payment of the cost of the works. Much of the plant will undoubtedly serve a much longer time, but if it is outgrown the works have been paid for by the generation which used them and our successors have no reason to complain if they have to rebuild.

Perhaps it should be said, however, that building water works for the immediate future may not always bring glory to the engineer; the public is likely to forget, if they ever know, that the works were designed to be outgrown in a given time, and the engineer

may be severely criticised for his poor judgment and lack of foresight. On the other hand, the builders of the Roman aqueduct have received no end of praise because they built so unnecessarily well as to have their work stand for centuries after its usefulness had passed.

CAPACITY OF THE PLANT.

The capacity of the distributing system is determined, in the case of the small town, by the fire protection requirements solely. One good effective fire stream will use water at as great a rate as will the ordinary town of five thousand inhabitants during the hours of maximum draft; and a distributing system, therefore, designed to give adequate fire protection will at all times give an ample supply for domestic purposes. The capacity of the source, however, is determined not by the demand for fire protection, which at most lasts but a few hours, but by the more constant demand for domestic purposes. An exception to this occurs in the case of the system which is not provided with sufficient reservoir capacity to store the amount of water required for the greatest conflagration when it is necessary to have a source of supply which will yield a large quantity of water in a short time.

The quantity of water which will be drawn from the sources of supply depends upon the population to be supplied, the character of the residences supplied, the care taken to prevent leaks and other wastes, and the use of water for manufacturing or mechanical purposes.

Attempts to estimate closely the future population are in nearly all cases very unsatisfactory. There are so many circumstances which may arise in any town — and especially the small town — which will have a great influence upon the population and which cannot be foretold, that estimates are likely to be of comparatively little value. The construction of a large factory may double the population of a town of three thousand within a few years, and, on the other hand, the loss of a large industry may cause a loss of half the population.

Illustrations have already been given of cases where the popula-

tion has increased or decreased at a rate which could not possibly have been foretold. However, some estimate must be made in order to arrive at the quantity of water likely to be required, and undoubtedly the best way to do this is to study the past growth of the town in question, together with the growth of other towns similarly situated which are now larger than the town being studied. A good way to make such a study is illustrated in Fig. 2. A group of towns of larger population than the one in question

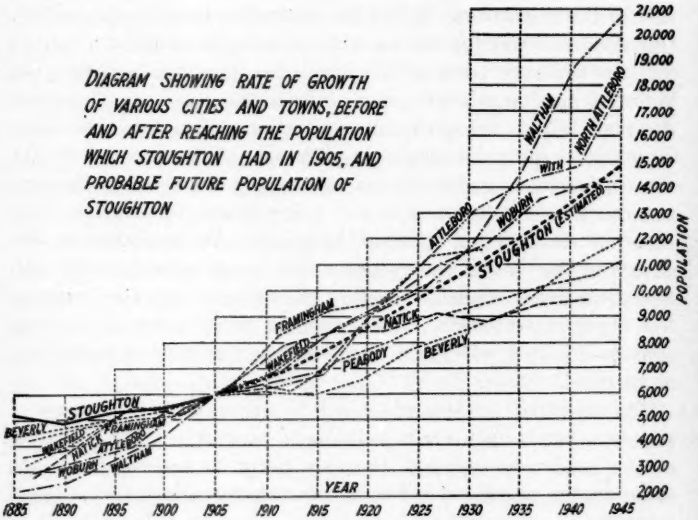


FIG. 2.

but which have been somewhat similarly situated with respect to railroad facilities, proximity to larger towns, facilities for manufacturing, etc.; is selected. The population, by census periods, of each of these towns is then plotted in such a way that the curves of population will all meet at the point which represents the present population of the town in question. This shows in a graphical way what may be expected if the town in question grows at the same rate that any one of the other towns grew after it had reached

the present population of the town being studied. A study of such a diagram with a thorough knowledge of the local conditions in each of the places considered will enable one to make as good an estimate as is possible.

The quantity of water which will be drawn from the sources by a given population depends very largely upon the care taken to prevent leaks and other wastes and the use of water by manufacturers or other large consumers.

The efforts which are made to prevent leaks and other wastes have a great effect upon the per-capita consumption. Unfortunately experience has shown that while it is possible by rigid inspection and by testing to make the water system practically water tight in the beginning, it is not safe to count on continued efforts in this direction, and it must be assumed, in designing works, that at least average conditions will prevail.

The quantity of water used by manufacturers or for mechanical purposes is, many times, — especially in a small community, — a very large proportion of the total use. While these uses cannot be considered domestic uses, it is generally considered good policy to supply such customers. Sometimes the quantity required for these purposes can be known in advance and can be allowed for in designing the works, but in other cases it is necessary to include the possibility of such uses in making the final guess as to the quantity of water which will be required.

The increasing per-capita consumption of water is also something which should be considered. The causes for this increase have been frequently enumerated, and they are largely what may be designated as legitimate. The number of plumbing fixtures in houses and the greater quantity of water required for each fixture are among the chief reasons. Although for many years prophecies have been made that this increase would stop, it still continues, and water-works systems must be constructed to meet this demand for an increased quantity of water.

A future per-capita domestic consumption of from 75 to 100 gal. per day for ordinary small towns does not seem unlikely, and in the case of towns having large estates and a large area of well-kept lawns the consumption may be much larger.

In estimating the future consumption of water there is danger of

counting on what might be or should be, rather than figuring on what experience teaches is likely to be.

The average daily consumption of water per inhabitant in seventeen Massachusetts towns having a population of less than 3 000, excluding towns used as summer resorts, is 40 gal. The maximum in the above group is 62 gal. In 18 towns having a population of from 3 000 to 6 000 the average consumption is 50 gal., with a maximum of 102 gal. The consumption in 9 small towns used as summer resorts is 96 gal., with a maximum of 185 gal. These figures are averages for the year, and are much exceeded during certain months.

REQUIREMENTS FOR FIRE PROTECTION.

The requirements for fire protection are responsible for a large proportion of the cost of the small water-works system. In fact, excepting at the source of supply, as far as construction is concerned the furnishing of water for domestic purposes is only incidental. The fire protection requirements determine the pressure to be maintained, the size of the distributing reservoir, the sizes of the street mains, and, in some instances, the size of the pumping plant. These portions of the plant could be made much smaller and much less expensive were it not for the need for fire protection.

Messrs. Metcalf, Kuichling, and Hawley, in a paper before the American Water Works Association,* state that "the cost of the portion of the water-works plant involved by fire protection probably constitutes from 60 to 80 per cent. of the entire cost of the physical property in the case of communities having less than five thousand population." This is undoubtedly true except in those places where it is necessary, in order to secure water of sufficient purity for domestic purposes, to go to a large expense in obtaining it or in its purification.

It is certain that the cost of furnishing fire protection constitutes such a large proportion of the total cost of the plant that every effort should be made to make this portion of the plant as efficient as possible, getting the greatest possible return for the money. If the reservoir is of large capacity but the pipes are small, much

* Proceedings, 1911, p. 55.

of the cost of the reservoir is practically wasted. If the hydrants are not properly spaced, the advantages of large distributing mains are to a considerable extent lost.

The representatives of the insurance companies have taken the lead in making the water-works systems more efficient for fire protection, and the designing engineers and superintendents have unfortunately acted as a drag and in many cases have prevented the expenditures of comparatively small amounts of money which were needed to keep the large sums which have been spent from being practically wasted.

The fire protection feature in small water-works systems is of comparatively recent origin, and many of the earlier systems installed in small places were constructed for domestic service only. The importance of protection from fire and the inducements of lower insurance rates have created a demand for better fire-fighting facilities, so that this function of a small water-works system is now almost as important as the furnishing of water for domestic purposes.

Before the advent of the trained insurance engineer, the requirements of the companies were not always as consistent as they generally are now. In one case I have been asked to change the size of the main pipe from the standpipe to the village from 12 in. to 18 in., because we "don't like to have the main from the standpipe less than 18 in."; and this request was made without any information in regard to the pressure or the distance to the village. On the other hand, I found a village which boasted one hydrant. and the insurance rates on all property within 500 ft. were reduced on this account. The one hydrant was supplied from a 2-in. pipe which brought water to a neighboring drinking fountain under a static head of 40 ft., and was of little more value as a protection from fire than the town pump.

Now, the requirements of the insurance companies are likely to be reasonable, or at least there are good reasons for the requirements, and one of the duties of the designer of the water-works system is to balance these reasons with other considerations, with which he should be familiar, but to which insurance men are not expected to give so much weight.

In a small town it is usually necessary to depend entirely on

hydrant streams without the use of steamers, and it is essential, therefore, that the works, either by themselves or assisted by some outside source, should furnish both the requisite quantity of water and the proper pressure with which to fight the greatest conflagration which is likely to occur, and to do this under the most unfavorable conditions in regard to domestic consumption and quantity of water in reservoir or standpipe.

The standard fire stream is now considered to be that thrown by a 1⅛ in. smooth nozzle discharging 250 gal. per minute, and it is generally considered by the insurance engineer that a hose stream which does not throw 200 gal. per minute is not a good stream. There are many cases, however, when smaller streams throwing from 150 to 175 gal. per minute would furnish a reasonable protection, and all that a town would be justified in providing in some districts. It should always be remembered that in the outlying sections of small towns any fire which gets sufficient headway in the ordinary building, so that it cannot be conquered with two streams of 150 to 175 gal. each, is not likely to leave much of value if it is extinguished by using six streams. In such cases the value of the water is chiefly in saving adjacent buildings, and for this purpose even small streams are of great value.

For streets in a district where the houses are small and occupy comparatively large lots, with no prospect of any considerable increase in density of population, and where extensions of the mains are not likely, a hydrant which will furnish 300 gal. per minute under a suitable head to any building in the territory supposed to be covered by this hydrant will be good fire protection. More is desirable, but the advantages are not sufficiently great to warrant the expense of larger mains to secure it.

In a district where the houses are nearer together but containing no business blocks, apartment houses, or other large buildings, it should be possible to get 500 or 600 gal. per minute at any point.

Where there are business blocks and other large buildings, and where the buildings are very close together, as they frequently are in the center of a small village, it should be possible to get 1 000 gal. per minute. When there are factories or other special fire risks, a much larger quantity may e necessary, and a special study should be made of each case.

The pressure required at the hydrants while the hydrants are being used should be great enough to force the water through the greatest length of hose which will be used, and throw it to a sufficient height to cover any building. The hydrant spacing and the pressure should, therefore, bear some relation to each other. The following table, taken from a paper by Mr. E. V. French,* gives the limit of a good, efficient fire stream with different lengths of good cotton, rubber-lined hose, with a constant pressure of 60 lb. at the hydrant, and also the amount of water which would be discharged.

ONE 1½-IN. STREAM FLOWING FROM A SMOOTH-BORE NOZZLE.

Length of Hose.	Limit of Height, with Moderate Wind, as a Good, Effective Fire Stream.	Gallons per Minute Flowing.
100	67	250
200	59	222
300	52	206
400	44	188
500	40	178
700	33	158
1 000	25	140

The table shows the importance of having hydrants near the buildings to be protected. Unless the hydrants are near enough to furnish water at the fire under a good pressure, the expense of large pipes and a high reservoir is largely wasted. The cost of a two-way hydrant in place is about $40, and in the ordinary distribution system about 8 hydrants are required per mile of street main to keep the hydrants within 250 ft. of every building in the territory covered; so that the expense of the hydrants is very small compared with the expense incurred in other parts of the system to obtain efficient fire protection; and the saving of two or three hydrants is poor economy if the efficiency of the other portions of the system is wasted thereby. There is an opportunity for the exercise of judgment in the location of the hydrants, and they should not be placed, as is the case in many towns, to meet the wishes of the influential property owners. In general,

* JOURNAL N. E. W. W. A., *25*, 249.

hydrants should not be more than five hundred feet apart in the outlying sections. In the more closely built-up sections they should be so spaced as to make it possible to get the number of streams which are considered necessary at any particular point with the use of not more than about three hundred feet of hose for each stream. This figure may be modified, however, if the pressure is unusually high, and should be if the pressure is unusually low.

The minimum pressure desirable for good fire protection with hydrants spaced as suggested is about 50 lb. per sq. in. at the hydrants when they are in use. This pressure will give, with 300 ft. of best quality hose and $1\frac{1}{8}$-in. nozzle, a stream of 185 gal. per minute, which can be thrown to a height of 44 ft. With 200 ft. of hose the quantity thrown would be about 200 gal. per minute, and the height would be increased to 50 ft. There are cases where in the higher sections of the town these pressures are almost impossible, and in such places the hydrants should be so located as to require as little hose as possible.

In the case of thickly built-up villages, the pressure should be 60 lb. per sq. in. at the hydrant when the water is being drawn at the maximum rate. This pressure will give a stream of more than 200 gal. per minute with 300 ft. of hose, and with 200 ft. of hose will send 222 gal. per minute to a height of about 60 ft.

The size of the mains depends entirely on the requirements determined on to give fire-fighting facilities, and on the head available. When these are known, the system can readily be designed. Generally, however, the head which can be secured is not fixed but can be made whatever is desired by putting in additional expense, and the determination of the most economical arrangement of height of reservoir, size of pipes, and spacing of hydrants is a matter for careful study.

The rule adopted in many places to put in no street main less than 6 in. in diameter in most cases works out properly, but there is no excuse for it as an arbitrary rule. A short street will many times be better served with a 4-in. pipe than other streets in the same system with 6-in. mains, and the money saved by using the smaller pipe could well be expended in strengthening those parts of the system which are weaker. The standard should be the quantity of water the pipe will deliver and the head under

which it delivers this amount. If a 4-in. pipe will do this satisfactorily there is no good reason why it should not be used.

The loss of head due to friction in a 6-in. pipe which has been in the ground for some time, when water is being drawn at the rate of 300 gal. per minute, is about 10 ft. per 1 000 ft. of length, and this figure, together with the required pressure at the hydrant of 50 lb. per sq. in., should in general determine the allowable length of 6-in. pipe as a dead end.

PUMPING PLANTS.

The development of the oil and gasoline engines has done much to make water-works systems for small places financially possible. When the only feasible pumping machinery was the steam pump, the cost of installation of pumps and boilers, the cost of the pumping station to house them, and the cost of maintaining the plant, made a water supply practically out of the question unless a gravity supply could be secured. With the new form of engine, however, the conditions are quite different. The cost of the machinery has been greatly reduced, the cost of the station is much less, and the cost of operating is reduced to a minimum on account of the fact that with oil or gasoline there is no consumption of fuel except while work is being done, while with a steam plant a large proportion of the coal is used in banking the fires and getting up steam.

Electricity is also becoming an important factor in connection with small pumping plants, although the cost of current is so great that there are few places where oil or gasoline are not more economical, except for auxiliary plants used only occasionally.

Pumps should usually be designed for the greatest economy in doing the work which they are called upon to do regularly in supplying the domestic needs of the town without regard to their use for five protection purposes. It is seldom feasible in the small system to have pumps of sufficient capacity to be of very great value in case of fire, and dependence for fire protection should be placed on water stored in a reservoir or large standpipe or tank, or on some connection with factory pumps through which a large supply of water can be quickly secured. With increased size of

TABLE 1.

Town.	Population. (1910.)	Date of Introduction of Works.	Average Daily Consumption. (Gallons).	Number of Pumps.	Capacity of Each Pump. (Gals. per 24 Hrs.)	Hours Required to Pump Average Daily Consumption.		Kind of Power Used.
						With Whole Plant.	With One Unit.	
Orange	5 282	1873	161 000	2	800 000	2.4	4.8	Water and steam
Lincoln	1 175	1874	221 000	2	750 000	3.0	7.1	Steam
					1 000 000	...	5.3	
Nantucket	2 962	1878	233 000	5	400 000	2.5	14.0	Steam, gasoline and oil
					400 000	...	14.0	
					600 000	...	9.3	
					600 000	...	9.3	
					250 000	...	22.4	
Mansfield	5 183	1883	569 000	2	720 000	9.5	19.0	Steam
Wellesley	5 412	1884	374 000	2	1 000 000	3.7	9.0	Steam
					1 440 000	...	6.2	
Franklin	5 641	1884	296 000	4	1 000 000	1.3	7.1	Steam
					1 500 000	...	4.7	
					1 500 000	...	4.7	
					1 500 000	...	4.7	
Sharon	2 310	1885	149 000	2	350 000	2.7	10.2	Steam
					1 000 000	...	3.6	
Kingston	2 445	1886	.....	2	300 000	...	...	Water and electricity
Grafton	5 705	1886	114 000	2	500 000	1.8	5.5	Steam
					1 000 000	...	2.7	
Easton	5 139	1887	135 000	2	700 000	2.3	4.6	Steam
Tisbury	1 196	1887	.....	2	1 000 000	...	...	Steam
Ayer	2 797	1887	162 000	2	500 000	2.6	7.8	Water and steam
					1 000 000	...	3.9	
Needham	5 026	1890	356 000	3	750 000	2.8	11.4	Steam
					750 000	...	11.4	
					1 500 000	...	5.7	

Foxborough	3 863	1891	234 000	2	720 000	3.9	7.8	Steam
Reading	5 818	1891	234 000	2	900 000	3.1	6.2	Steam and electricity
Provincetown	4 369	1893	212 000	2	1 000 000	2.5	5.1	Steam
North Brookfield	3 075	1893	224 000	2	1 000 000	2.7	5.4	Electricity
Onset	....	1894	71 000	2	500 000	1.9	3.4	Steam
					400 000	...	4.3	
Fairhaven	5 122	1894	400 000	4	500 000	2.1	19.2	Steam
					840 000	...	11.4	
					1 500 000	...	6.4	
					1 700 000	...	5.6	
Longmeadow	1 084	1895	93 000	2	720 000	1.6	3.1	Oil and steam
					648 000	...	3.4	
Millbury	4 740	1895	190 000	2	750,000	2.7	6.1	Steam
					1 000 000	...	4.6	
Rutland	1 743	1896	99 000	2	250 000	1.9	9.5	Steam
					1 000 000	...	2.4	
Weston	2 106	1896	106 000	4	150 000	2.0	16.9	Steam and electricity
					300 000	...	8.5	
					350 000	...	7.3	
					500 000	...	5.1	
Walpole	4 892	1896	538 000	2	1 500 000	4.3	8.6	Steam
Winchendon	5 678	1896	182 000	2	1 000 000	1.7	4.4	Steam and electricity
					1 500 000	...	2.9	
Billerica	2 789	1898	165 000	2	960 000	2.1	4.1	Steam
North Andover	5 529	1898	261 000	2	1 500 000	2.1	4.2	Steam
Shirley	2 139	1903	64 000	1	120 000	12.8	12.8	Power from mill
Merrimac	2 202	1904	88 000	2	1 000 000	0.9	2.1	Steam
					1 250 000	...	1.7	
Edgartown	1 191	1906	61 000	2	421 200	1.8	3.5	Oil
Oxford	3 361	1906	.....	2	720 000	...	...	Oil
Dracut	3 461	1906	53 000	2	288 000	2.2	4.4	Gasoline
North Chelmsford	5 010	1907	70 000	2	288 000	2.9	5.8	Electricity
Wrentham	1 743	1908	96 000	2	360 000	3.2	6.4	Oil
Westford	2 851	1908	71 000	1	500 000	3.4	3.4	Electricity

TABLE 1.—*Continued.*

Town.	Population. (1910.)	Date of Introduction of Works.	Average Daily Consumption. (Gallons).	Number of Pumps.	Capacity of Each Pump. (Gals. pe. 24 Hrs.)	Hours Required to Pump Average Daily Consumption.		Kind of Power Used.
						With Whole Plant.	With One Unit.	
Marion	1 460	1908	115 000	2	1 008 000	1.4	2.7	Oil
Bedford	1 231	1909	30 000	2	360 000	1.0	2.0	Gasoline
East Brookfield	....	1909	.....	2	125 000	...	...	Oil
Pepperell	2 953	1909	110 000	2	360 000	3.7	7.3	Oil
Blandford	717	1909	.....	1	108 000	...	...	Gasoline
Douglass	2 152	1910	.....	2	350 000	...	...	Electricity
					187 000	...	...	
Dudley	4 267	1910	124 000	2	360 000	4.1	8.3	Electricity
Medway	2 696	1911	.....	2	504 000	...	...	Oil
Leicester, Cherry Valley and Rochdale	....	1911	.....	2	288 000	...	...	Oil
Ashland	1 682	1911	20 000	2	216 000	1.1	2.2	Oil
Norton	2 544	1912	.....	2	432 000	...	...	Oil
Barnstable	4 676	1912	75 000	1	1 000 000	1.8	1.8	Oil
Littleton	1 229	1912	41 000	1	350 000	2.8	2.8	Oil
Acton	2 136	1912	.....	2	432 000	...	...	Oil
West Groton	....	1912	18 000	1	120 000	3.6	3.6	Gasoline
West Brookfield	1 327	1913	.....	1	360 000	...	...	Electricity
Mattapoisett	1 233	1913	.....	2	360 000	...	...	Oil

pumps it is necessary to have a larger force main, a larger suction pipe, more wells, if the supply is taken from driven wells; in fact, a considerable portion of the plant must be increased in size and made more expensive in order to operate large pumps. It is generally an expensive mistake to the design the pumps for anything but the domestic service.

Large pumps are somewhat more efficient than small ones, and if an attendant remains at the station while the pumps are in operation there is a saving in the shorter hours required with the large pump. With the oil engine, however, or with electricity, constant attendance is unnecessary, especially in the case of the smaller plants.

Pumping machinery should always be provided in duplicate, and works, although designed to run most economically when one unit is in operation, can be operated if necessary at double capacity with a somewhat reduced efficiency. A plant designed for a community which will use from 100 000 to 150 000 gal. per day, should generally have a capacity of about 250 gal. per minute for each unit. This would mean the operation of one of the pumps for from six to ten hours each day. Such a plant would give two large fire streams, in case of fire, by starting both of the pumps.

Many of the pumping plants are undoubtedly of too large capacity for economy, and the tendency is in recent years to make them smaller — especially when the power used is some form of explosive engine.

Table 1 gives the capacity of the pumps in many of the small plants in Massachusetts, as compared with the average daily consumption. In using the table it should be remembered that some of the plants have only been recently installed and the consumption has not yet become normal, and that in other places the summer consumption is much in excess of the average daily consumption. The towns are arranged in order of the date of introduction of works, in order that the effect of the newness of the plant may be more easily discounted.

DISTRIBUTING RESERVOIR.

The design of the distributing reservoir is affected chiefly by the topography, the requirements for fire protection, and by the

facilities for pumping. In a much less degree it is affected by the water consumption.

The effect of the topography upon the design is generally to change the reservoir from what is desirable to what is feasible. In a comparatively flat country it is practically impossible to store as much water at as great an elevation as is desirable, and in such cases the distributing reservoir must be cut down, and other portions of the system must be designed to do the work which should properly be done by the distributing reservoir. For example, in a perfectly flat country where a high standpipe is the only feasible form of reservoir, the reservoir at most will only be a means of making it possible to pump for a few hours each day, and will furnish enough water to supply the hydrants until water can be pumped into the mains. In such a case it is necessary to provide pumping capacity either at the pumping station or by connection with fire pumps in some factory sufficient to furnish all the water which will be required for fire protection, and, as the pressure in such a system will necessarily be lower than is desirable, valves may have to be provided so that the pressure can be increased over that furnished by a full standpipe.

When the topography is such that it is feasible to build a reservoir of any desired size and any height, the design is dependent almost entirely upon the requirements for fire protection. The pressure furnished from the reservoir should be such as to give the required quantity of water at the proper pressure for fighting fires, and as this depends also on the size of the pipes, the pipe sizes and the reservoir pressure have to be considered together. The cost of pumping the water must also be considered. Generally it is found that the most economical static pressure from the reservoir at the point where there is likely to be the greatest demand for water is from 80 to 100 lb., depending to a large extent upon the distance from the reservoir to the center of distribution.

The maximum desirable pressure is a matter on which there is much disagreement, but the limit is constantly being extended. If it should prove to be more economical to have a system where the pressures run up to 150 lb., there would seem to be no good reason why this should not be done in a new system of water

works, and it would be likely to prove much more satisfactory than to maintain two levels.

In 86 small towns in Massachusetts the average static pressure in the central portion of the town is 79 lb. per sq. in. Nine of these towns have pressures of less than 50 lb.; 33 have pressures of from 50 to 75 lb.; 31, from 75 to 100 lb.; and in 13 the pressure is more than 100 lb.

The reservoir should be, if feasible, large enough to hold at the required elevation, in addition to the domestic supply for twenty-four hours, a sufficient quantity of water with which to fight any fire which is likely to occur. A fire in the built-up portion of a village may take about 1 000 gal. per minute or 60 000 gal. per hour. In general, the time during which this quantity will be required will not be more than from two to four hours. Applying this rule to the ordinary town with no large fire risks, the capacity of the reservoir or standpipe should be from 300 000 to 400 000 gal. During the time in which the water is being drawn from the reservoir it will generally be possible to start the pumps, which will add a certain amount of water, and if there are connections with fire pumps in factories these can also be brought into use.

The practice in Massachusetts is shown in Table 2, which gives such statistics as I have been able to get together for the smaller towns.

The capacity of the reservoir or standpipe as given in the table is the total capacity, and in the case of tall standpipes includes much water which is of little use in case of fire on account of the low pressure near the bottom of the standpipe.

I do not propose to discuss the relative merits of the steel standpipe and the reinforced concrete tank. Personally, I have no objection whatever to the use of the steel standpipe other than it is a blot on the landscape. In this respect also the concrete is not always superior to steel, for a leaky concrete reservoir is no ornament, and many of the concrete structures do leak. It seems to be largely a question of economy, keeping in mind the cost of maintaining the steel standpipe in repair but not making the mistake of assuming that the durability of the concrete will make the concrete tank good for all time, for the usefulness of any tank is likely to be passed by the time that a steel tank would be worn out.

TABLE 2.

Town.	Population. (1910.)	Date of Introduction of Works.	Average Daily Consumption. (Gallons.)	Capacity of Standpipe or Reservoir. (Gallons.)	Number of Days' Supply in Reservoir or Standpipe.	Quantity Remaining after Drawing One Day's Consumption.	Number of 250-Gallon per Minute Streams which could be Supplied for One Hour from Quantity in Preceding Column.	Additional 250 Gal. per Min. Streams which could be Supplied by Operating All Pumps.
Orange	5 282	1873	161 000	3 000 000	18.6	2 839 000	189.0	4.4
Lincoln	1 175	1874	221 000	1 500 000	6.8	1 279 000	85.3	4.9
Nantucket	2 962	1878	233 000	425 000	1.8	192 000	12.8	6.3
Mansfield	5 183	1883	569 000	242 000	0.4	Empty	None	4.0
Wellesley	5 412	1884	374 000	1 969 000	5.3	1 595 000	106.5	6.7
Franklin	5 641	1884	296 000	423 000	1.4	127 000	8.4	15.3
Sharon	2 310	1885	149 000	188 000	1.3	39 000	2.6	3.8
Kingston	2 445	1886	.....	264 000	...	.....	....	1.6
Grafton	5 705	1886	114 000	110 000	1.0	Empty	None	4.2
Cohasset	2 585	1886	291 000	1 500 000	5.2	1 209 000	80.6	2.8
Easton	5 139	1887	135 000	242 000	1.8	107 000	7.0	3.9
Tisbury	1 196	1887	.....	118 000	...	.....	....	2.8
Ayer	2 797	1887	162 000	1 440 000	8.9	438 000	29.3	4.2
Canton	4 797	1889	386 000	468 000	1.2	82 000	5.5	...
Avon	2 013	1890	80 000	212 000	2.7	132 000	8.8	...
Needham	5 026	1890	356 000	314 000	0.9	Empty	None	8.3
Foxborough	3 863	1891	234 000	282 000	1.2	48 000	3.2	4.0
Reading	5 818	1891	234 000	530 000	2.3	296 000	19.7	5.0
Holliston	2 711	1891	69 000	300 000	4.4	231 000	15.4	...
Manchester	2 673	1892	305 000	1 030 000	3.4	725 000	48.3	29.1
Provincetown	4 369	1893	212 000	460 000	2.2	248 000	16.5	5.6
North Brookfield	3 075	1893	.....	2 950 000	...	.....	....	5.6
Onset	....	1894	71 000	94 000	1.3	23 000	1.5	2.5
Ipswich	5 777	1894	323 000	3 000 000	9.3	2 677 000	178.0	...
Fairhaven	5 122	1894	400 000	500 000	1.3	100 000	6.7	12.6
Rockport	4 211	1895	306 000	317 000	1.0	11 000	0.7	...
Longmeadow	1 084	1895	93 000	80 000	0.9	Empty	None	3.8
Millbury	4 740	1895	190 000	1 500 000	7.9	1 310 000	82.3	4.9

Rockport	4 211	1895	306 000	317 000	1.0	11 000	0.4	3.8
Longmeadow	1 084	1895	93 000	80 000	0.9	Empty	None	3.8
Millbury	4 740	1895	190 000	1 500 000	7.9	1 310 000	82.3	4.9
Rutland	1 743	1896	99 000	250 000	2.5	151 000	10.1	3.5
Weston	2 106	1896	106 000	400 000	3.8	294 000	19.6	3.6
Walpole	4 892	1896	538 000	672 000	1.2	134 000	8.9	8.3
Winchendon	5 678	1896	182 000	547 000	3.0	365 000	24.3	7.0
Groton	2 155	1897	98 000	1 174 000	12.0	1 076 000	71.7	...
Billerica	2 789	1898	165 000	433 000	2.6	268 000	17.9	5.3
North Andover	5 529	1898	261 000	1 000 000	3.8	739 000	49.3	8.3
Falmouth	3 144	1899	310 000	755 000	2.4	445 000	29.7	...
Shirley	2 139	1903	64 000	200 000	3.1	136 000	9.1	0.3
Merrimac	2 202	1904	88 000	420 000	4.8	332 000	22.2	6.3
Edgartown	1 191	1906	61 000	200 000	3.3	139 000	9.3	2.3
Oxford	3 361	1906	.....	214 000	...	.....	....	4.0
Dracut	3 461	1906	53 000	225 000	4.2	172 000	11.5	1.6
North Chelmsford	5 010	1907	70 000	350 000	5.0	280 000	18.6	1.6
Wrentham	1 743	1908	96 000	264 000	2.8	168 000	11.2	2.0
Westford	2 851	1908	71 000	490 000	6.9	419 000	28.0	1.4
Marion	1 460	1908	115 000	235 000	2.0	120 000	8.0	5.6
Bedford	1 231	1909	30 000	235 000	7.8	205 000	13.7	2.0
Brookfield	2 204	....	.....	.....	...	.....	....	...
East Brookfield	....	1909	.....	184 000	...	.....	....	0.7
Pepperell	2 953	1909	110 000	476 000	4.3	366 000	24.4	2.0
Blandford	717	1909	.....	200 000	...	.....	....	0.3
Plainville	1 385	1909	37 000	246 000	6.6	213 000	14.2	0.3
Douglass	2 152	1910	.....	214 000	...	.....	....	1.5
Dudley	4 267	1910	124 000	770 000	6.2	646 000	43.1	2.0
Medway	2 696	1911	.....	424 000	...	.....	....	2.8
Leicester, Cherry Valley and Rochdale	3 237	1911	.....	394 000	...	.....	....	1.6
Ashland	1 682	1911	20 000	300 000	15.0	280 000	18.7	1.2
South Hadley, District No. 2,	4 894	1911	.....	432 000	...	.....	....	2.0
Norton	2 544	1912	104 000	200 000	1.9	96 000	6.4	2.4
Barnstable	4 676	1912	75 000	367 000	4.9	292 000	19.5	2.8
Littleton	1 229	1912	41 000	288 000	7.0	247 000	16.5	1.0
Acton	2 136	1912	.....	503 800	...	.....	....	2.4
West Groton	....	1912	18 000	212 000	11.7	194 000	12.9	0.3
Mattapoisett	1 233	1913	.....	330 500	...	.....	....	2.0
West Brookfield	1 327	1913	.....	250 000	...	.....	....	1.0

WEIGHT OF PIPE.

The portion of the design in which theory plays the smallest part and in which even experience is apt to count for little is the determination of the thickness and weight of cast-iron mains. The static pressure which pipes have to withstand and the breaking strength of the cast iron, are the only elements in determining the proper thickness of the pipes which are even approximately known, and determining the thickness from these elements alone would give pipes of about the thickness of cardboard. For example, a 12-in. pipe, to sustain a pressure of 100 lb. per sq. in., should theoretically have a thickness of shell of one twenty-seventh of an inch. All else in the determination of the thickness is in the nature of guesswork.

The formula used by this Association is —

$$t = \frac{pr}{\frac{1}{5}(16\,500)} + \frac{p'r}{\frac{1}{5}(16\,500)} + 0.25,$$

in which t is the thickness of the shell in inches; r, the radius of the pipe; p, the static pressure in pounds per square inch; p', an assumed water hammer in pounds per square inch; 16 500, the breaking strength of cast iron; and 5, a factor of safety.

Fig. 3 shows the thickness of a 6-in. and a 12-in. pipe for a pres-

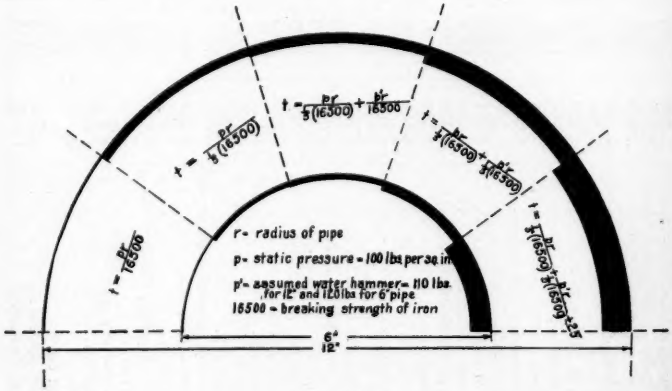

r = radius of pipe
p = static pressure = 100 lbs per sq in
p' = assumed water hammer = 110 lbs. for 12" and 120 lbs for 6" pipe
16500 = breaking strength of iron
6"
12"

FIG. 3.

sure of 100 lb. per sq. in., built up from this formula. The thickness, using the breaking strength of cast iron and the static pressure, is shown on the left; then with the factor of safety of 5 applied; then with allowance for water hammer of 120 lb. per sq. in. for the 6-in. pipe, and 110 lb. per sq. in. for the 12-in. pipe, using the breaking strength of the iron; then the added thickness for water hammer, applying the same factor of safety; and finally on the right the total thickness of the pipe, adding the 0.25 of an inch for anything which has been left out in the other determinations. It will be seen that the element of guess is the largest element in the determination of the thickness, and that the static pressure has very little relation to the final result. It is also apparent that, if the uncertainties which are provided for in these guesses can be reduced, the thickness can be made much less. The chief uncertainties are the water hammer, the corrosion of the pipe, the possibility of breakage in handling, the strains due to imperfect foundations or unequal settlement, and the eccentricity of the castings and other imperfections in the pipe.

There is no reason why the water hammer in a small town should not be kept well below the figures used in the formula. There are few, if any, authentic cases where corrosion of a cast-iron pipe has caused its failure. In fact, if a pipe has been in the ground long enough to corrode, it seldom fails from any cause. The strains due to imperfect foundations and settlement, in the case of small pipes, can be neglected if proper precautions are taken during construction. The difficulties due to imperfections in the casting and to the handling of thin pipes are the most serious, and to overcome these is the duty of the founders. There is no doubt that they will be overcome if the engineers insist on light pipe, for already much has been done along these lines; the cost per ton may be somewhat increased if lighter pipes are used, but this increased cost will be nothing like the saving accomplished by the use of the lighter pipe.

In my own practice I have put in many miles of Class C pipe where the pressures run up to 115 lb. per sq. in., and have never known of a failure which would have been prevented by using thicker pipe. The breakage in the handling may or may not have been greater. In any case it was not excessive.

For the ordinary conditions in a small town, I would never use a heavier pipe than the Class C, and lighter pipes may safely be used in many cases.

In fourteen of the recently constructed systems in Massachusetts, Class C pipe has been used exclusively; in five places two or more classes have been used in the same town for different pressures. In two towns the A. W. W. Assoc. Class C pipe, corresponding practically to the N. E. W. W. Class F, has been used, and in one town A. W. W. Class B, which corresponds approximately to N. E. W. W. Class D, was used.

DEPTH OF PIPES.

The depths to which street mains should be laid have been investigated by a special committee of this Society,* and the experience of the cold winter of 1911–12 has given valuable if unpleasant experience to those who have had charge of works. The depth determined on affects the cost of the works materially, especially if rock is encountered, and if it is safe to reduce the depth it certainly should be done.

Theoretically, street mains might be laid at different depths in different soils, being a foot nearer the surface in clay than in gravel; but in the average New England town there are so many soils that it is not feasible to make any distinction. The only distinction which it would appear safe to make is in the case of places where the ground water always stands near the surface, where the pipes may be laid in shallow trenches. The freezing of the pipes is such a serious matter that it would seem to be unwise to take any chances in an attempt to save money on trench excavation. The best practice seems to be, for a climate like that of Massachusetts, to have the center of the pipe from 4.75 ft. to 5.00 ft. beneath the surface.

The recent practice in Massachusetts is indicated by the returns from twenty-four towns in which water-works systems have been built in the last ten years. In twelve of the twenty-four towns the pipes are covered to a depth of 4.5 ft. In four towns they were laid in a 5-ft. trench, in three towns the cover was 4 ft., in

* JOURNAL N. E. W. W. A., *23*, 435; *27*, 160.

four towns they were covered 4 ft. 9 in., and in one town the center of the pipe was 5 ft. below the surface of the ground.

The service pipes in 7 of the above towns are laid 5 ft. deep; in 10, 4.5 ft. deep; and in two places they were laid 4 ft. deep.

In small towns where there is no established grade for the streets, changes in the street level are likely to occur; and when these can be foretold, as is possible in some cases, provision should be made for such changes in laying the pipes; but here again it is unwise to go too far into the future, for the expected is liable never to happen, and frequently money spent in anticipation of changes in grade is money wasted.

There are many interesting problems connected with the crossing of streams and the carrying of the pipes over railroads concerning which there is little printed information, and a discussion of which by the members of this Association would bring out many points of great value. Many of the elaborate bridges which have been constructed are undoubtedly needless, and on the other hand there are many cases where pipes carried directly on the highway bridges have given much trouble both by leaking joints and by freezing. These important details cannot be discussed within the limits of this paper.

FINANCIAL PROBLEMS.

Perhaps one of the most serious problems which confronts those interested in the construction of a water-works system in a small town is the problem of convincing the voters that a water-works system will not bankrupt the town. There are always those who believe that a water-works system is not necessary or desirable, that the water obtained from private wells is better than that which has been stored in pipes or reservoirs, and that the notion that well water may be injurious to health is nonsense. Such men are generally not to be convinced by any argument which can be put forward. They are the men who object on principle to improved roads, improved schools, and improvements of any kind. But there are always in every town thinking men who honestly believe that the construction of a water-works system would be such an expensive undertaking that it would be a

TABLE 3.

Town.	Population. (1910.)	Date of Introduction of Works.	Length of Mains. (Miles.)	Cost of Works to Date.	Cost per Mile.	Cost per Inhabitant.
Reading	5 818	1891	32.1	$345 000‡	$10 730‡	$59.30‡
Winchendon	5 678	1896	23.5	184 173	7 850	32.40
Franklin	5 641	1884	18.0	275 000	15 270	48.80
North Andover	5 529	1898	34.0	208 000	6 120	37.60
§Westborough	5 446	1879	16.0	175 000	10 930	32.20
Wellesley	5 412	1884	41.0	416 457	10 150	76.90
Orange	5 282	1873	15.0	200 000	13 330	37.80
Mansfield	5 183	1888	21.3	129 426	6 090	25.00
Easton	5 139	1887	10.0	100 000	10 000	19.45
Needham	5 026	1890	39.3	185 000	4 710	36.80
North Chelmsford	5 010					
Fire District		1907	6.0	80 000	13 330	....
South Hadley	4 894					
District No. 1	....	1872	7.0	120 000	17 150	....
§District No. 2	....	1911	6.0	68 000	11 320	....
Walpole	4 892	1896	22.44	176 871	7 880	36.20
Provincetown	4 369	1893	12.0	125 000	10 400	28.60
Foxborough	3 863	1891	12.1	126 000	10 400	32.60
§Dalton	3 568	1884	5.0	100 000	20 000	28.05
Dracut	3 461	1906	6.9	69 463	10 060	20.10
Leicester	3 237					
§Leicester District	....	1891	8.4	68 658	8 175	....
Cherry Valley and Rochdale	....	1911	15.1	108 245	7 160	....
Falmouth	3 144	1899	43.5	333 643	7 670	106.00
North Brookfield	3 075	1893	9.2	194 828	21 200	63.40
Pepperell	2 953	1909	21.0	124 000	5 900	42.00
Ayer	2 797	1887	12.0	140 516	11 700	50.30
Billerica	2 789	1898	10.4	99 772	9 575	35.80
Medway	2 696	1911	13.0	113 000	8 690	41.90
Manchester	2 673	1892	21.0	447 044	21 250	167.00
Kingston	2 445	1886	12.0	75 000	6 250	30.70
Hopkinton	2 452	1884	8.0	65 000	8 130	26.50
Sharon	2 310	1885	17.3	105 145	6 075	45.50

Deerfield	2 209					
§Deerfield District	....	1911	5.0	31 000	6 200	....
§Wayland	2 206	1878	5.9	45 000	7 630	20.40
Brookfield	2 204					
East Brookfield	....	1909	2.7	28 000	10 320	....
Merrimac	2 202	1904	9.0	86 500	9 610	39.30
Groton	2 155					
†West Groton District	....	1912	3.0	26 000	8 670	....
§Holden	2 147	1905	11.0	74 946	6 810	34.90
*Shirley	2 139	1903	7.0	56 285	8 050	26.30
Acton	2 136	1912	11.5	100 000	8 690	46.90
§Hadley	1 999	1905	8.0	61 004	7 625	30.50
Rutland	1 743	1896	4.5	30 000	6 670	17.20
Wrentham	1 743	1908	11.0	67 500	6 130	38.70
Ashland	1 682	1911	7.5	55 000	7 330	32.70
§Shelburne	1 498	1912	9.7	87 278	9 010	58.20
§Huntington	1 473	1899	5.0	35 000	7 000	23.70
Marion	1 460	1908	14.3	130 500	9 150	89.40
Millis	1 399	1891	10.0	60 000	6 000	42.80
*Plainville	1 385	1909	6.5	45 344	6 980	32.70
†West Brookfield	1 327	1913	6.1	45 000	7 380	33.90
Mattapoisett	1 233	1913	7.0	65 000	9 290	52.70
Bedford	1 231	1909	6.2	66 995	10 800	54.40
†Littleton	1 229	1912	7.0	60 000	8 575	48.75
Lincoln	1 175	1874	25.0	181 000	7 240	154.00
§Erving	1 148	1896	5.6	46 000	8 220	40.10
§Hinsdale	1 116	1889	4.0	37 000	9 250	33.10
Longmeadow	1 084	1895	12.0	50 000	4 170	46.20
§Russell	965	1911	7.0	50 000	7 140	51.80
†Blandford	717	1909	4.8	34 000	7 080	47.50
§Egremont	605	1913	3.5	20 000	5 720	33.10

* Has no pumping plant.
† Has only one pumping unit.
‡ Including filter plant.
§ Gravity systems.

TABLE 4.

Cost of Pumping Stations, Pumping Machinery, and Distributing Reservoirs in Recently Constructed Water-Works Systems.

Town.	Population. (1910.)	Pumping Station.			
		Material.	Size.	Cost.	Cost per Sq. Ft.
Ashland	1 682	Cobbles	22 x 30	$1 935	$2.93
Bedford	1 231	Brick	19 x 36	1 857	2.71
Deerfield	....	Cobbles	9 x 12	350	3.24
Dracut	3 461	Wood and steel shingles over entire surface.	.....	1 730	...
Dudley	4 267	Brick	24 x 26	1 948	3.12
East Brookfield	....	Brick	24 x 30	1 628	2.26
East Douglass	2 152	Brick	20 x 35†	2 500	3.57
Leicester (Cherry Valley and Rochdale)	....	Brick	30 x 40	2 368	1.97
Littleton	1 229	Brick	24 x 34	3 100‡	3.80‡
Marion	1 460	Brick	.....	....	...
North Chelmsford	5 010	Brick	33 x 23	2 000	2.64
Oxford	3 361	Brick	24 x 24	2 000	3.46
Pepperell	2 953	Brick	28 x 38	2 852	2.68
So. Hadley (Fire Dist. No. 2.)	....	Brick	25 x 36	2 700	3.00
Wareham	....	Brick	25 x 36	2 133‖	2.37‖
West Groton	....	Brick	16 x 16	500‖	1.95‖
Wrentham	1 743	Brick	25 x 36	1 647‖	1.83‖

Town.	Pumping Machinery.			
	Pumps.	Engines.	Cost.	Cost per Horse-Power.
Ashland	2–7 x 8	2–18 h.p. Oil	$4 358	$121.00
Bedford	2–8½ x 10	2–25 h.p. Gasoline	4 000	80.00
Deerfield	1–4 x 6	1–7½ h.p. Motor	475	63.30
Dracut	1–8 x 10	1–20 h.p. Gasoline	1 783	89.15
Dudley	2–8 x 10	2–25 h.p. Motors	2 500	50.00
East Brookfield	2–5½ x 8	2– 8 h.p. Oil	3 100	193.75
East Douglass	1–10 x 10 1–7¼ x 10	1–35 h.p. Motor 1–15 h.p. Motor	2 455	49.10
Leicester (Cherry Valley and Rochdale)	2– 8 x 10	2–18 h.p. Oil	4 414	122.50
Littleton	1–7½ x 10	1–25 h.p. Oil	3 960	158.50
Marion	2–7½ x 8*	2–40 h.p. Oil	8 157	102.00
North Chelmsford	2–7½ x 10	2–25 h.p. Motors	3 500	70.00
Pepperell	2– 8 x 10	2–25 h.p. Oil	6 200	124.00
South Hadley (Fire Dist. No. 2)	2– 8 x 10	2–35 h.p. Oil	6 875	98.25
Wareham	2– 8 x 10	2–25 h.p. Oil	5 642	112.80
West Groton	1– 6 x 8	1–10 h.p. Gasoline	1 163	116.30
Wrentham	1– 8 x 10	1–25 h.p. Oil	2 821	112.80
Wrentham State School	2– 6 x 8	2–10 h.p. Motors	1 784	89.20

* Double acting.

† Two stories.

‡ Includes some grading.

‖ Without pumping machinery foundations.

TABLE 4. — *Continued.*

Town.	Distributing Reservoir.					
	Kind.	Size, Diameter, Height.	Capacity (Gals.)	Cost of Foundation.	Cost, including Foundations.	Cost per 1 000 Gallons.
Ashland	Concrete Standpipe	40 x 32	300 000	....	$5 812	$19.35
Bedford	Steel Standpipe	20 x 100	235 000	$1 030	6 640	28.25
Dracut	Reservoir	.....	225 000	....	2 385	10.60
Dudley	Reservoir	71 x 26	770 000	....	20 232	26.20
East Brookfield	Steel Standpipe	25 x 50	184 000	300	3 550	19.30
East Douglass	Concrete Standpipe	45 x 18	214 000	....	4 524	21.15
Leicester (Cherry Valley and Rochdale)	Concrete Standpipe	40 x 21	197 000	....	4 976	25.25
Littleton	Steel Standpipe	35 x 40	288 000	700	4 638	16.10
Marion	Steel Standpipe	20 x 100	235 000	....	5 883§	25.00§
North Chelmsford	Steel Standpipe	22 x 125	355 000	....	9 772	27.50
Oxford	Steel Standpipe	27 x 50	214 000	400	5 060	23.60
Pepperell	Steel Standpipe	45 x 40	476 000	839	6 707	14.10
Plainville	Steel Standpipe	25 x 67	246 000	710	4 979	20.25
So. Hadley (Fire Dist. No. 2)	Steel Standpipe	35 x 60	432 000	....	6 165§	14.30§
Wareham	Steel Standpipe	20 x 100	235 000	....	6 835§	29.10§
West Groton	Steel Standpipe	30 x 40	212 000	613	4 021	18.95
Wrentham	Steel Standpipe	30 x 50	264 000	800	6 000	22.70
Wrentham State School	Steel Standpipe	22 x 50	142 000	368	2 596	18.25

§ Without foundation.

Note. — All pumps are vertical, single-acting, triplex pumps, unless otherwise noted.

great mistake for the town to enter into it. The best solution of this problem — the problem of convincing the honest doubters — is to use the experience gained by other towns of similar size which have already put in works. With this in view, I have collected certain information from the small towns in Massachusetts which have been supplied with water, and tabulated the returns. The great difficulty in getting together this information is the lack of proper systems of accounts. In most cases it is impossible to obtain information of any value from the printed reports, and in many cases it cannot be obtained even from a study of the books. The officials themselves cannot dig out the information. Construction accounts and maintenance accounts are hopelessly mixed, and the vouchers in many cases do not show for what the money has actually been spent.

Perhaps it is only fair to say here that the salaries of superintendents in small towns are from fifty dollars per year up — and some of them do not go very far up, either. As the superintendent is generally, to use the language of one of them, "registrar, clerk of board, draftsman, engineer, etc.," it is not strange that the sys-

tem of accounts is not very elaborate. The average salary of the superintendents in towns having steam pumping systems is $1 080. The average salary of those where pumping is done by oil engines or electric motors is $818. Of the latter group practically all operate the pumps themselves.

Table 3 gives the best figures which I have been able to obtain as to the total cost to date of many of the small water-works systems in Massachusetts. Here I have found instances where the total cost of the works carried on the books has included the amount paid for maintenance each year. Such of these cases as have been found have been corrected, but there may be some which have not been discovered. Naturally the difference in local conditions makes a difference in the cost, but the table, with a general knowledge of the towns, contains some very valuable information.

Table 4 is also presented showing the cost of pumping stations, pumping plants, and distributing reservoirs.

For obvious reasons the plants which are owned by private companies are not included in the table, but in general it may be said that the cost, both of construction and of maintenance, of privately owned plants is fully as great as that of the plants owned by the towns.

DISCUSSION.

MR. EDWARD V. FRENCH.* As Mr. Johnson read his paper those of us who are always looking at the fire side were, I think, somewhat fearful at some of the limitations he was proposing; but as he went on he made it very clear that he was talking about the really small towns. As he developed the subject we saw that he was making a plea all the way through for the distribution of the money that is available over the whole system, so that every part of the town would get that protection which it needed from a fire standpoint and would not get less than it needed because some other part of the town got more. In other words, he was making a plea for the distribution of the service in proportion to the needs of the different sections. So, taking it all in all, although

*Vice-President and Engineer, Arkwright Mutual Insurance Company, Boston, Mass.

some of the figures seem small, I am inclined to think that it is really a very reasonable limitation which he places upon the amount of fire protection, such, for instance, as that to be provided for the sparsely built-up sections. Following the lines which he has suggested, a small town would get a fire system which would give it reasonably good fire protection in every part, and, as Mr. Johnson has stated, if you get that, there will always be sufficient water for other purposes.

Mr. Johnson's remarks about 4-in. pipe were somewhat heretical, as we have looked at it, but, perhaps with some modification, they may nevertheless be reasonable. He has in mind a district that is very little built up. If we take a street which has no hydrant on it, the chief use of the pipe through it is to carry water for domestic purposes, and in that case there may be a place, in spite of all we have said in the past, for a 4-in. pipe. I suppose Mr. Johnson would modify his suggestion to this extent: that if the various cross-feeders, which we might think he means to make 4 in., are part of a gridiron system, and consequently necessary to bring into any section a liberal amount of water, then the 4-in. pipe becomes too small. That is, it may be all right as a single local feeder, but we must not get away very far from the good old rule that 4-in. pipe should be treated gingerly, and used, when used at all, with a great deal of good judgment.

Mr. Johnson mentioned the mill fire pump. Those of us who are interested in the protection of mill properties would always be very glad to advise our people to allow the use of their fire apparatus for the good of the town. We have always done so in the past, and before pollution was a danger this used to be done a good deal. In later days many of those connections have had to be cut off or safeguarded in some way. While the mill people are more than willing to help, the conditions from the standpoint of health are such that this use of the mill fire pump can be made only when the water it discharges will be unpolluted, or possibly in the rare case where a little chance might be taken because the danger might be less than that which a sweeping fire would cause to health and even life.

MR. S. H. MACKENZIE.* Mr. Johnson said he thought 150 lb.

* Superintendent Water-works, Southington, Conn.

pressure was not objectionable in a water system. We noticed last year, when feeding from a high-service reservoir, that our meter readings were uniformly increased, which shows that leaky fixtures will waste more water and that good fixtures will become worn much quicker under the greater head. It seems to me that for domestic service from 80 to 100 lb. would be preferable to 150 lb. It would of course be advisable to have the mains of such size as to maintain the pressure as near uniform as possible.

MR. JOHNSON. I might say in answer to that, that I limited it to new systems. It seems to me it makes all the difference in the world whether it is a new system of water works or an old system. In a new system, where the plumbing is new and can be made to resist the pressure, I think it is much better to get up to 150 lb. than it is to try to maintain two different pressures in the same town.

MR. R. D. CHASE. When the city of Springfield was considering the Little River supply, this subject was studied quite carefully, with the result that the whole city was put on one service, bringing the previous low-pressure service up to from 135 to 145 lb. I think there has been no serious trouble, and I believe no one now regrets the change to the higher pressure. Quite a number of towns were visited in course of the studies where pressures as high as 150 lb. were in use without serious objection.

In regard to one point which Mr. Johnson made about the isolated stations: I recall that in Westfield, Mass., there is a small water-driven electric-light plant supplying a hotel about a mile distant. A private telephone line connects the station with the hotel office. At the station the receiver is always off the hook, so that at any time from the hotel one can listen to the operation of the plant. I see no reason why this could not be done at the very small pumping station.

MR. A. R. HATHAWAY.* The lower level, or down-town portion, of Springfield was formerly supplied by the old low-service system which gave a maximum pressure of about 35 lb. The larger number of old tenement premises were located in this section. At that time the high-service supply from Ludlow gave a maximum pressure of about 135 lb. in this lower portion, but was

* Water Registrar, Springfield, Mass.

not used for these tenements because of the old and weak plumbing.

When the supplies were both superseded by the new supply from Little River, with a maximum pressure of about 145 lb. in the down-town section, it became necessary to replace the service pipes for this class of property with new and stronger pipes from the street main to the building. The cost of these services was equitably divided between the property owner and the water department. Pressure regulators were also installed between the new services and the old plumbing, the consumer paying only the actual cost of same to the department. In this manner we overcame the objection spoken of, and the consumers having become accustomed to the new situation, we now have very little trouble.

MR. FRANK L. FULLER.* When the Wellesley works were built in 1884 we had occasion to cross the railroad on an overhead bridge. The pipe, which was put in a box filled with tan-bark, froze the first winter. Since then, when we have had other occasions to cross the same railroad, we have used two boxes with an air space between, and have had no trouble.

In the town of Ware, in 1886, we had occasion to cross a stone arch bridge, where there was a covering of only about a foot of earth over the arch stones. We placed a drinking fountain so that there was a continuous flow in the pipe over the arch, and there never was any trouble from freezing.

At Franklin, N. H., we had to cross the river on an old toll bridge, which had considerable span and so little stiffness that when teams were passing there was a good deal of vibration. The pipes were strapped together with long rods and gave no trouble.

In regard to the weight of pipe, I think there has been a great deal of iron pipe laid which was unnecessarily heavy. I have generally recommended for 6-in. pipe, 30 lb. to the foot; for 8-in., somewhere in the neighborhood of 43 or 44 lb.; for 10-in., 60 lb., and for 12-in., 75 lb. This may seem light and less than some of our standards, but if you will reckon up and see what the difference of a few pounds per foot will amount to in eight or ten miles, you will find it is quite a large sum of money. I believe that if the

* Civil Engineer, Boston, Mass.

pipe is heavy enough to stand railroad transportation and the teaming from the freight station to the place where it is laid, there will be no trouble on account of pressure. I believe that the corrosion of the pipe will not be sufficient to affect its strength during the length of time it will be in the ground.

MR. HENRY A. SYMONDS. When we come to make improvements, or repairs, or extensions, I think in probably one out of every half dozen plants in the state that were built more than fifteen years ago we find that the sizes of pipes are very much out of proportion to the particular service which they were supposed to render. That was in many cases, perhaps, due to the inability of the builders of the works to size up the requirements that the plant would be subjected to. But in many cases it was due to lack of knowledge of what these systems were able to accomplish.

That brings to my mind a case where I was called in a few years ago, which perhaps illustrates how some or at least how one of our water commissions design and build water works. A certain town in the central part of the state laid out a small piping system. They submitted the matter to me a little later, for although it was supposed to be a gravity supply, they could not get the water into the town and they could not exactly see why, for the plan showing the lay-out of the pipes gave the elevation of the reservoir as considerably above the town. On a little investigation it developed that, while there was a valley coming down to the town, it was somewhat roundabout, so the water commissioners, not thinking it necessary to get any expert advice, decided that the correct thing to do in this case was to put in a siphon; and so they had piped straight over a hill to the town and had gone to an elevation of about 100 ft. above the reservoir.

The placing of hydrants is always a matter which, it seems to me, is worked out on an entirely wrong principle, and how to remedy it is considerable of a problem. The rate is ordinarily made in accordance with the number of hydrants. Mr. Johnson has pointed out to us very clearly how the expense of increasing the number of hydrants amounts to but little compared with the expense of the whole plant. Here is a plant, perhaps, which may cost $75 000, and an expenditure of $40 apiece additional, we will say, for twenty or thirty hydrants, may make all the difference

between a plant which is first class from the insurance point of view and one which is entirely inadequate to take care of the service. But the town is starting out in the face of so much per hydrant, which has got to be paid year after year, and the result is that in four cases out of five the hydrants are cut down to about two thirds of what the number should be.

I wish also to express my approval of the idea that Mr. Johnson has spoken of in regard to 4-in. pipe. There are many places where a 4-in. pipe is entirely sufficient; for instance, on short cross streets. It has a very much greater length of life than wrought-iron small pipes, and the expense of installing it is comparatively small.

In regard to breakage of pipe, a case came to my attention on a pumping plant where, after the pump was installed, they began to have breaks. The pipes were not very heavy, but they seemed to be as heavy as the service required, and at first we were entirely at a loss to know what the trouble was. Finally on an examination of one of the pumps it was found that there was something defective with the packing, so that they were pumping air into the pipe. The result showed that this was the cause of the breakage, because immediately upon repacking the pump the breaking stopped.

MR. RAYMOND W. PARLIN.* There were one or two points in Mr. Johnson's paper which I would like to corroborate from the experience of the American Water Works and Guarantee Company. One of them is that in some thirty plants which they control they have made a practice of using Class A of the American Water Works specifications, which is practically the same as Class C of the New England Water Works Association specifications. They have used this pipe up to 125 lb. pressure and have had no trouble with it.

One of the main troubles with private water company operation, and also with municipal plant operation, comes from a lack of education of the public. The water-works officials often do not realize that the ordinary citizen wants to know a little something about the plant which is supplying him with water, and as the result of their ignorance the people often get misconceptions

* Resident Engineer, Washington County Water Company, Maryland.

which cause trouble. One case, for instance, is the use of a filtered supply as an emergency source. One city of about 22 000 population had an emergency source which was perfectly good if filtered, the use of which saved some $15 000 a year. The people, not knowing why that source was used, not knowing that the saving would mean a less rate to them, always put up a great complaint every time the company started to use it. They would say, "You ought to have provided for this in the first place." The fact is, if the company had provided for it in the first place, a lot of unnecessary capital would have been required, and it would have been necessary to have increased the rates in order to make proper earnings.

In the matter of fire protection, very often the efficiency of a plant is not dependent on the design or on the operation, but it is dependent on the fire department, which is altogether outside the control of either the engineer or the water-works officials. I have seen the fire department connect up with two lines of hose from a hydrant 600 or 700 ft. away, and leave a hydrant within 150 ft. of the fire unused. I have seen them connect up an engine to a hydrant within 200 ft. of the fire, and run an ordinary hose line from a hydrant 500 or 600 ft. away, and of course the engine spoiled the streams from the hydrant. Now, if you have that sort of service in your fire department, they are going to spoil even a good water system, or if the water system is just right they will defeat its purpose. In the case I speak of, the water system was just on the edge. If it was carefully handled at fires they had plenty of water for practically every portion of the city, but under the careless way in which it was handled they got very poor protection. Yet in that particular city, as the result of one examination by the insurance companies, they practically omitted the fire department from their criticism, when really it was responsible for most of the trouble.

I think Mr. Johnson's criticism as to pressure is illustrated very well in a town in Maryland where the original system was designed for a pressure of 55 lb., with the idea of using fire engines for bad fires. Subsequently the pressure was increased, causing leaks all over the town which were due entirely to the plumbing having been installed under the old pressure. An unfortunate thing in

that case was that one of the first leaks occurred in the house of the mayor, and it started trouble right off. That was a case of a privately owned company.

MR. FRENCH. Even in a rather small town there is sometimes a fairly well built-up section; the houses may not all be very near together, but they are all in a certain area. Now, although a single house in a small area, well separated, may be protected by the small quantities of water Mr. Johnson mentions, it is very easy for a small town to have a fire which will spread into various sections. I remember when the village of Fryeburg in Maine burned, I reached there soon after the fire started, and found, when I came into the town, two or three houses perhaps a quarter of a mile back from the scene of the main fire burning, having been ignited by sparks. Under those conditions the small water-works system may be called upon to supply water at several points simultaneously. This feature must not be forgotten, and is another reason why we must be very careful about using 4-in. pipe.

PROPOSED
STANDARD SPECIFICATIONS FOR POST HYDRANTS.

[Adopted at the special meeting, April 15, 1914.]*

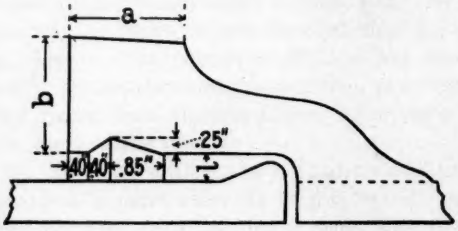
FINAL REPORT OF THE COMMITTEE.

1. Size.

a. The size of hydrants shall be designated by the nominal diameter of the valve opening, which must be at least 4 inches for hydrants having two 2½-in. hose nozzles; 5 inches for hydrants having three 2½-in. hose nozzles; and 6 inches for hydrants having four 2½-in. hose nozzles, and shall be classed as one-way, two-way, three-way, or four-way, according to the number of 2½-in. hose outlets for which they are designed.

b. The net area of the waterway at the smallest part other than at the valve opening when the hydrant is wide open must not be less than 120 per cent. that of the valve opening, and there must be sufficient clear waterway through the hydrant when wide open to allow the passage of a ball at least *1⅞** in. in diameter for a two-way and *2⅜** in. for three- and four-way hydrants.

In new designs it is recommended that inside diameter of hydrants, especially at the outlets, be 7 in. for two-way and 8 in. for three- and four-way hydrants.



c. Hydrants must be fitted with bell ends to fit standard cast-

* The parts of this report printed in italics have been referred back to the committee for further consideration or revision.

TABLE 1.

Nominal Diam. Inches.	Classes.	Actual Outside Diameter. Inches.	Pipe Sockets.		"a."	"b."
			Diameter. Inches.	Depth. Inches.		
6	All	7.10	7.90	3.00	1.50	1.40
8	All	9.30	10.10	3.50	1.50	1.50

iron pipe, the dimensions of which are given in Table 1, or with flanges of standard dimensions and having standard bolt layouts, as given in Table 2. Holes are not to be drilled on the center line, but symmetrically each side of it.

TABLE 2.

Size of Pipe. Inches.	Diameter of Flange. Inches.	Flange Thickness at Edge. Inches.	Diameter of Bolt Circle. Inches.	Number of Bolts.	Size of Bolts. Inches.
6	11	1	9½	8	¾ x 3
8	13½	1⅛	11¾	8	¾ x 3½

Where working pressure is from 150 to 250 lb., the standard for heavy flanges must be used.

2. General Design.

a. Hydrant may be of compression or gate type.

b. Hydrants must be designed to safely withstand a working pressure of 150 lb., with a factor of safety of at least 5 at the working pressure. For example, a hydrant whose working pressure is 150 lb. must resist a pressure of 750 lb. before breaking.

c. Valve when shut must remain reasonably tight when upper portion of barrel is broken off.

There is some danger of the hydrant being broken off, and in such cases it is desirable to have the hydrant gate remain reasonably tight.

d. Any changes in diameter of the water passage through the hydrant must have easy curves, and all outlets must have rounded corners of good radius.

e. * *With the hydrant discharging 250 gal. per minute through each 2½-in. hose outlet, the total friction loss of the hydrant must not exceed 1¾ lb. for two-way, 2¼ lb. for three-way, and 3 lb. for four-way hydrants, except when fitted with inside hose gate valves, in which cases the loss must not exceed 2¾ lb. for three-way and 3½ lb. for four-way hydrants.*

f. Hydrants must be so designed that with extraordinary usage they will not cause an increase of pressure in the system above normal of more than 60 lb.

g. Hydrants must be fitted with two lugs so that the leaded joint underground can be strapped.

h. When hydrant barrel is made in two sections, the upper flange connection must be at least 2 in. above the ground line.

In clayey soils where the ground packs closely about the hydrant and tends to grip it, freezing and consequent heaving of the ground would bring some strain on the hydrant, especially if there were flanges near the ground level. To overcome this effect the flanges should be put above ground and the hydrant surrounded from bottom to ground level with a 3-in. layer of gravel. About ½ bu. of small stones should be placed around the base of every hydrant to serve as a drain, unless the drip from hydrant is connected to some waste pipe.

3. Material of Body.

a. The hydrant body must be made of cast iron.

4. Materials.

a. The metal for all iron castings must be of good quality, and of such character as shall make the metal strong, tough, and of even grain, and soft enough to satisfactorily admit of drilling and machining. The metal must be made without any admixture of cinder iron or other inferior metal, and must be remelted in a cupola or air furnace. The castings must be smooth, free from scales, lumps, blisters, sand holes, and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

Specimen bars of the metal used, each being 26 in. long by 2 in. wide and 1 in. thick, must be made without charge as often as the

* The parts of this report printed in italics have been referred back to the committee for further consideration or revision.

engineer may direct, and in default of definite instructions, the manufacturer must make and test at least one bar from each heat or run of metal. The bars when placed flatwise upon supports 24 in. apart, and loaded in the center, must support a load of 1 900 lb., and show a deflection of not less than .30 in. before breaking; or if preferred, tensile bars may be made which must show a breaking point of not less than 21 000 lb. per sq. in., bars to be cast as nearly as possible to the dimensions without finishing, but corrections may be made by the engineer for variations in width and thickness, and the corrected result must conform to the requirements.

*b.** *All wrought iron or mild steel used must be of the best quality of double refined iron, of a tensile strength of at least 50 000 lb. per sq. in.*

c. All composition or other non-corrodible metal used must be of the best quality, to have a tensile strength of not less than 30 000 lb. per sq. in., with 5 per cent. elongation in eight diameters and 5 per cent. reduction of area at breaking point. Composition for inside hose valve stems must have a tensile strength of not less than 55 000 lb. per sq. in. and an elastic limit of not less than one half the tensile strength.

5. Hose Valves and Nipples.

a. Hydrants must have at least two hose connections.

b. If hose gate valves are used they must be of the outside detachable type or be built inside the barrel. The outside hose gate valves must be made of composition or of iron with composition trimmings, with lugs cast on the valve body, and each valve must be bolted to the hydrant by two $\frac{3}{4}$-in. tap bolts, spaced horizontally $5\frac{5}{8}$ in. on centers. The valves must not project further than necessary, and must be of the inside screw type, placed in a vertical position, with the hand-wheel at least 3 in. below the base of the operating nut.

Inside hose-gate valves must have composition metal working parts and be of rugged design, and must not introduce an unnecessary friction loss. There must be ample clearance between

* The parts of this report printed in italics have been referred back to the committee for further consideration or revision.

the gate and the hydrant body when the gate is in any position. The gate and parts should be interchangeable, and the valves should be located so as to be as accessible as possible for repairs. The gate must be designed so that it cannot come off in use. The top of the stem must be below the level of the hydrant stem nut, so that the hydrant wrench can be freely operated.

c. Hose nipples must be of composition metal threaded with a fine thread into the hydrant, and securely pinned or carefully locked and calked in place. If desired, the nipple may be cast with two side lugs and be bolted to the hydrant.

d. Hose threads on all hydrants to be installed in any given district must of necessity be interchangeable with those already in service, but, where practicable, threads should conform to the National Standard. The essential features of the "National Standard" thread in the $2\frac{1}{2}$ in. size are a 60 degree V-thread, outside diameter on male threads of $3\frac{1}{16}$ in. and $7\frac{1}{2}$ threads per inch.

e. The stems of the hose valves must be not less than $\frac{3}{4}$ in. in diameter for the $2\frac{1}{2}$-in. valves, and not less than $\frac{7}{8}$ in. in diameter for the valves at the steamer connections.

f. The stem nut of all inside hose and steamer connection gate valves must be $\frac{1}{2}$ in. square.

6. Hydrant Valve.

a. The valve seat must be made of composition metal securely threaded in place.

b. The valve must be faced with a yielding material, such as rubber or leather, except that if of the gate type, a bronze ring may be used. The valve must be designed so that it can be easily removed for repairs without digging up the hydrant.

c. The clearance of parts must be such that corrosion will not make the parts inoperative.

7. Drip Valve.

a. A positively operating non-corrodible drip valve must be provided and arranged so as to drain the hydrant when the main valve is shut.

b. The seat of the drip valve must be made of non-corrodible

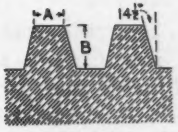
metal and must be securely fastened in the hydrant. All other parts of the drip mechanism must be designed to be easily removed without digging up the hydrant.

8. Operating Stem.

a. The threaded section of the operating stem when located in the waterway must be of composition or other non-corrodible metal, but when above the stuffing box it may be of wrought iron, or mild steel.* The operating stem, where it passes through the stuffing box and gland, must be of composition metal or be fitted with a composition metal covering. The diameter of the operating stem at base of thread must not be less than $1\frac{1}{8}$ in. for gate type of hydrant and 1 in. for compression and toggle types. The remainder of stem may be of iron and the diameter must not be less than $1\frac{3}{8}$ in. for gate type of hydrant and $1\frac{1}{4}$ in. for compression and toggle types. The operating stem must be attached, so that in operation it will be impossible for it to become detached.

b. The stem must terminate at the top in a nut of pentagonal shape, finished with slight taper to $1\frac{1}{2}$ in. from point to flat, except for hydrants to be installed where existing hydrants have different shape or size of nut, in which case the additional hydrant must have the same operating nut as the old ones for uniformity. The nut socket in the wrench must be made without taper so as to be reversible.

c. The thread which operates the valve must be Acme, half V or square. The Acme standard thread is shown in Fig. 1.



$$A = \frac{0.3707}{\text{No. of threads per inch}}$$

$$B = \frac{1}{\text{Twice No. of thds. per inch}} + .01"$$

FIG. 1.

9. Stuffing Box and Gland.

a. The stuffing box and gland must be of composition metal or bushed with it. If a packing nut is used, it must be of composition metal. The bottom of the box and end of the gland or packing nut must be slightly beveled.

* The iron threaded section is permissible only where the hydrants are to receive the best of care and be kept oiled, otherwise composition must be used to insure reliable operation.

b. Gland bolts or studs must be of composition metal, wrought iron, or steel, at least ½ in. in diameter. The nuts must always be of composition metal.

10. Hydrant Top.

a. The hydrant top must be designed so as to make the hydrant as weatherproof as possible, and thus overcome the danger of water getting in and freezing around the stem. Provision must be made for oiling both for lubrication and to prevent corrosion. A reasonably tight fit should be made around stems.

b. There must be cast on the hydrant top, in characters raised ⅛ in., an arrow at least 2½ in. long, showing direction to open, and the word " OPEN " in letters ¾ in. high.

11. Hose Caps.

a. Hose caps must be provided for all hose outlets, and must be securely chained to the barrel with a welded chain of wire, not less than ⅛ in. in diameter.

b. The hose cap nut must be of the same size and shape as the operating nut.

c. A leather or rubber washer must be provided in the hose cap, set in a groove to prevent its falling out when the cap is removed. If desired, a lead washer or disk may be used, so retained in the cap that it will not fall out.

12. Marking.

a. Hydrants must be marked with the name or trademark of the manufacturer and the year of manufacture. All letters and figures must be cast on the hydrant well above the ground line. They must be 1 in. high and raised ⅛ in. on the casting except the date mark, which may be abbreviated, and may be smaller if legible.

13. Testing.

a. Hydrants, after being assembled, must be tested to at least 300 lb. per sq. in. before leaving the factory. If the working pressure is over 150 lb. per sq. in. the hydrants must be

tested to twice the working pressure. The test should be made with the valve open in order to test the whole barrel for porosity and strength of hydrant body. A second test should be made with the valve shut in order to test the strength and tightness of the valve.

b. Hydrants must be fully opened and closed before shipping in order to test the freedom and strength of the parts. The conditions of the test should be made as severe as are liable to occur in service when using a hydrant wrench at least 17 in. long.

14. Direction to Open.

a. All hydrants must open to the left (counter-clockwise), except where existing hydrants open to the right, in which case additional hydrants should turn the same as the old ones for the sake of uniformity.

H. O. LACOUNT, *Chairman,*
GEORGE A. STACY,
FRANK A. MCINNES,
FRED W. GOW,
WILLIAM F. SULLIVAN,
Committee.

PROCEEDINGS.

Special Meeting.

Hotel Brunswick,
Boston, Mass., April 15, 1914.

President Frank A. McInnes in the chair.

The following members and guests were present:

Members.

A. F. Ballou, L. M. Bancroft, G. W. Batchelder, A. E. Blackmer, E. M. Blake, C. A. Bogardus, George Bowers, E. C. Brooks, C. A. Carpenter, R. D. Chase, J. C. Chase, R. C. P. Coggeshall, W. R. Conard, A. W. Cuddeback, J. C. DeMellow, Jr., J. M. Diven, E. D. Eldredge, Patrick Gear, F. J. Gifford, A. S. Glover, Clarence Goldsmith, F. W. Gow, R. A. Hale, R. K. Hale, F. E. Hall, T. G. Hazard, Jr., A. R. Hathaway, D. A. Heffernan, D. J. Higgins, A. C. Howes, F. T. Kemble, E. W. Kent, Willard Kent, Patrick Kieran, A. C. King, G. A. King, H. O. Lacount, E. E. Lochridge, F. A. McInnes, James A. McMurry, A. E. Martin, John Mayo, F. E. Merrill, H. A. Miller, William Naylor, Henry Newhall, F. L. Northrop, R. W. Parlin, T. A. Peirce, J. A. Rourke, J. E. Sheldon, G. H. Snell, G. A. Stacy, T. V. Sullivan, W. F. Sullivan, H. L. Thomas, R. J. Thomas, E. J. Titcomb, G. W. Travis, C. H. Tuttle, J. C. Whitney, G. E. Winslow, I. S. Wood, F. H. Carter. — 64.

Associates.

Builders Iron Foundry, by A. B. Coulters; Chapman Valve Manufacturing Company, by V. N. Bengle, Robert Shirley, A. C. Pilcher, C. E. Pratt, and J. F. Mulgrew; Darling Pump and Manufacturing Company (Ltd.), by J. L. Hough and H. A. Snyder; Eddy Valve Company, by John Knickerbocker; Hersey Manufacturing Company, by Albert S. Glover and W. A. Hersey; Lead Lined Iron Pipe Company, by T. E. Dwyer; Ludlow Valve Manufacturing Company, by A. R. Taylor, J. H. Caldwell, and G. A. Miller; H. Mueller Manufacturing Company, by G. A. Caldwell; National Meter Company, by J. G. Lufkin; National Water Main Cleaning Company, by B. B. Hodgman; Norwood Engineering Company, by H. W. Hosford; The Pitometer Company, by E. D. Case; Pittsburgh Meter Company, by J. W. Turner; Pratt & Cady Company, by W. D. Cashin and E. L. King; Rensselaer Valve Company, by R. J. Rasmason; Ross Valve Manufacturing Company, by William Ross;

The Leadite Company, by C. A. Vance; A. P. Smith Manufacturing Company, by D. E. O'Brien and F. L. Northrop; Thomson Meter Company, by E. M. Shedd; Water Works Equipment Company, by W. H. VanWinkle; R. D. Wood & Co., by C. R. Wood and H. N. Simons; Henry R. Worthington, by Samuel Harrison; C. H. Millar & Son, by C. F. Glavin. — 34.

GUESTS.

R. C. Harlow, water commissioner, Plymouth, Mass.; W. O. Teague, D. Maynard Sullivan, Boston, Mass.; F. S. Loverrell, Providence, R. I.; H. F. Conant, superintendent water works, Attleboro, Mass.; E. F. Hughes, chairman water board, Watertown, Mass.; H. L. Sherman, Boston, Mass., and George Fred Whitney, Natick, Mass. — 8.

The Secretary presented applications for active membership, properly endorsed and recommended by the Executive Committee, from the following-named persons:

Wallace Willett, East Orange, N. J., consulting engineer, New York City; Fred L. Cushing, Medford, Mass., water registrar; Charles H. Smith, West Medford, Mass., engineer Associated Factory Mutual Fire Insurance Company; Walter H. Merchant, Jr., New Bedford, Mass., engineer both steam and water types of fire apparatus; Henry T. Gidley, Fairhaven, Mass., superintendent Fairhaven Water Company; Charles H. Mitchell, Toronto, Canada, consulting hydraulic engineer; Louis K. Rourke, Boston, Mass., general engineering; A. N. Beer, Ottawa, Ontario, engineer; Edward C. Sherman, Brookline, Mass., engineer engaged in private consulting practice; Fred A. Darling, Franklin, Mass., superintendent and chief engineer, Franklin Water Department; Herbert L. Sherman, Belmont, Mass., chemist and cement expert, president New England Bureau of Tests, Inc.; F. L. Fellowes, Vancouver, B. C., city and water works engineer, Vancouver.

On motion of Mr. Edwin C. Brooks, the Secretary was instructed to cast one ballot in favor of the applicants, and he having done so, they were declared duly elected members of the Association.

Mr. Clarence Goldsmith, assistant engineer, read a paper entitled "A Study of Cast-Iron Bell and Spigot Water Pipe Joints by the Public Works Department, City of Boston."

President McInnes then called Mr. George A. King to the chair, and the meeting proceeded to a discussion of the report of the Committee to Prepare a Standard Specification for Fire Hydrants.

The report was submitted in print, and the discussion was opened by Mr. H. O. Lacount, chairman of the committee. Other gentlemen who took part in the discussion were Mr. F. A. McInnes, Mr. Clarence Goldsmith, Mr. Elbert E. Lochridge, Mr. Frank L. Fuller, Mr. D. F. O'Brien, of the A. P. Smith Manufacturing Company; Mr. George A. Stacy; Mr. John Knickerbocker, president of the Eddy Valve Company; Mr. C. R. Wood, Mr. R. D. Chase, Mr. Walter O. Teague, Mr. Patrick Gear, Mr. Caldwell, and Mr. James M. Diven.

The principal discussion was in regard to the standard size of hydrants under Section 1*a*, which, as submitted by the committee, read as follows:

"Hydrants must be designated by the number of $2\frac{1}{2}$-in. hose outlets for which they are designed, the diameter of the valve opening being at least 5 in. for two-way and 6 in. for three- and four-way hydrants."

For this, by a vote of 30 to 13, on motion of Mr. J. M. Diven, was substituted the following:

Classification. The size of hydrants shall be designated by the nominal diameter of the valve opening, which must at least be 4 inches for hydrants having two $2\frac{1}{2}$-in. hose nozzles, 5 inches for hydrants having three $2\frac{1}{2}$-in. hose nozzles, and 6 inches for hydrants having four $2\frac{1}{2}$-in. hose nozzles, and shall be classed as one-way, two-way, three-way, or four-way, according to the number of $2\frac{1}{2}$-in. hose outlets for which they are designed.

The rest of the report was adopted, section by section, substantially as it came from the committee, and it was voted that the committee be continued, with instructions to confer with committees of the National Fire Protection Association and the American Water Works Association, with the view of securing uniform hydrant specifications.

WORCESTER, June 24, 1914.

The June meeting of the New England Water Works Association was held at Worcester, Mass., on June 24, 1914.

The following members and guests were present:

Members.

J. M. Anderson, G. W. Batchelder, W. U. C. Baton, A. S. Blackmer, J. W. Blackmer, C. A. Bogardus, J. Burnie, R. C. P. Coggeshall, J. E. Conley, F. W. Dean, J. M. Diven, J. Doyle, E. D. Eldredge, G. F. Evans, G. H. Finneran, T. C. Gleason, H. T. Gidley, P. Gear, F. E. Hall, D. A. Heffernan, A. C. Howes, J. A. Hoy, J. L. Hyde, A. W. Jepson, W. Kent, A. C. King, G. A. King, H. M. King, F. A. McInnes, W. A. McKenzie, H. McLean, J. Mayo, G. F. Merrill, H. A. Miller, J. W. Moran, A. S. Negus, J. A. Newlands, J. J. Philbin, S. H. Pitcher, W. H. Pitman, P. R. Sanders, H. W. Sanderson, C. D. Sharpe, G. H. Shaw, S. Smith, E. L. Stone, W. F. Sullivan, R. C. Sweetser, E. J. Titcomb, C. H. Tuttle, W. H. Vaughn, J. H. Walsh, R. S. Weston, W. J. Wetherbee, J. C. Whitney, F. B. Wilkins, F. I. Winslow, I. S. Wood, L. C. Wright. — 59.

Associates.

Chapman Valve Manufacturing Co., by J. T. Mulgrew; Hersey Manufacturing Co., by S. B. Greene; Lead Lined Iron Pipe Co., by Thomas E. Dwyer; Leadite Co., by C. A. Vance; Ludlow Valve Manufacturing Co., by A. R. Taylor and G. A. Miller; H. Mueller Manufacturing Co., by G. A. Caldwell; National Meter Co., by J. D. Lufkin; Rensselaer Valve Co., by C. L. Brown; A. P. Smith Manufacturing Co., by D. F. O'Brien and F. L. Northrop; Union Water Meter Co., by Edward Otis and D. K. Otis; R. D. Wood & Co., by H. M. Simons; Henry R. Worthington, by Samuel Harrison. — 16.

Guests.

Mrs. Geo. A. King, Miss L. C. King, Mr. and Mrs. W. B. Dean, Taunton, Mass.; W. L. Venuard, Lynn, Mass.; Mrs. Wm. F. Sullivan, Nashua, N. H.; Mrs. John Mayo, Miss Hopkins, Bridgewater, Mass.; R. J. McIntyre, N. E. Mather, P. J. Cannon, N. L. Howe, Clinton, Mass.; Mrs. F. A. McInnes, Mrs. H. A. Miller, Miss Joan M. Ham, Boston, Mass.; F. W. Dinwiddie, Gardner, Mass.; Mrs. Patrick Gear, Mrs. M. C. McLean, Miss Ellen Hanley, Marion McLean, Alphonse La Porte, Leo Bacon, Mrs. Hanley, Holyoke, Mass.; W. T. Dotten, Winchester, Mass.; Neddie Eldredge, Onset, Mass.; Mrs. G. E. Batchelder, Jos. Brosanan, Harold L. Hall, Frank H. McCormick, Edmund R. Garvey, Worcester, Mass.; Mrs. John E. Gleason, Ware, Mass.; Mrs. Willard Kent, Narragansett Pier, R. I.; Mrs. J. L. Boady, Chicago, Ill.; Chas. F. Glavin, Donaldson Iron Co., Emaus, Pa.; P. R. Cashin, Boston, Mass.; Nathan C. Rockwood, *Engineering News;* Mrs. H. M. King, Springfield, Mass.; Geo. C. Hunt, Mrs. Geo. C. Hunt, John E. Washburn, Geo. E. Adams, Clarence M. Hall, Henry C. Page, Peter G. Holmes, Robert F. Batchelder, Michael J. Keernan, A. S. Pero, P. M. Shea, A. D. Bates, Miss May Brenner, his Honor Mayor Wright of Worcester. — 51.

Members and guests left the Worcester Union Station in special trolley cars and motors for the Pine Hill Reservoir of the Worcester Water Supply, in process of construction; after inspection of the reservoir the party were conveyed to Lake Quinsigamond, where lunch was served at the club house of the Tatassit Canoe Club. Following lunch, addresses were made by the mayor of the city and others.

After a short business meeting, applications for membership properly endorsed and recommended by the Executive Committee were received from C. J. Callahan, Lewiston, Me.; August V. Graf, St. Louis, Mo.; C. T. Henderson, Milwaukee, Wis.; Fred O. Stevens, E. Weymouth, Mass.; D. A. Reed, Duluth, Minn.; The Cutler Hammer Mfg. Co., Milwaukee, Wis. They were by unanimous vote made members of the Association.

Members then availed themselves of the opportunity to witness the operation of the Austin trenching machine and to inspect the shops of the Water Department and their equipment.

EXECUTIVE COMMITTEE.

Meeting of the Executive Committee of the New England Water Works Association at headquarters, Tremont Temple, Boston, Mass., Wednesday, April 15, 1914.

Present, President Frank A. McInnes, William F. Sullivan, Robert J. Thomas, Samuel E. Killam, Lewis M. Bancroft, George A. King, and Willard Kent.

Twelve applications for membership were received, viz.:

Wallace Willett, mechanical engineer, 100 William St., New York, N. Y.; Charles H. Mitchell, consulting engineer, Toronto, Ont.; A. N. Beer, assistant engineer water works, Ottawa, Ont.; F. L. Fellowes, engineer water works, Vancouver, B. C.; Fred L. Cushing, water registrar, Medford, Mass.; Charles H. Smith, engineer Associated Factory Mutual Fire Insurance Company, Boston, Mass.; Walter H. Merchant, Jr., engineer of fire apparatus, Fire Department, New Bedford, Mass.; Henry T. Gidley, superintendent Fairhaven Water Company, Fairhaven, Mass.; Edward C. Sherman, consulting engineer, 6 Beacon St., Boston, Mass.; Fred A. Darling, superintendent water works, Franklin, Mass.; Herbert L. Sherman, president New England Bureau of Tests, Inc., 12 Pearl St., Boston, Mass.; Louis K. Rourke, commissioner of public works, 6 Wayne St., Roxbury, Mass.;

and the applicants were by unanimous vote recommended therefor.

Adjourned.

WILLARD KENT, *Secretary.*

Meeting of the Executive Committee of the New England Water Works Association was held at the Tatasit Club, Worcester, Mass., June 24, 1914.

Present: President Frank A. McInnis, and members William F. Sullivan, James W. Blackmer, George A. King, and Willard Kent.

Six applications were received, four for active membership, one for reinstatement, and one for associate, respectively:

C. J. Callahan, clerk water board, Lewiston, Me.; August V. Graf, assistant chemist St. Louis Water Works, St. Louis, Mo.; C. T. Henderson, electrical and mechanical engineer, P. O. Box 1564, Milwaukee, Wis.; Fred O. Stevens, superintendent water works, 114 Hawthorn St., E. Weymouth, Mass.; D. A. Reed, manager Water and Light Dept., Division of Public Utilities, Duluth, Minn.; The Cutler Hammer Mfg. Co., Milwaukee, Wis.; and the applicants were unanimously recommended for membership.

Adjourned.

WILLARD KENT, *Secretary.*

NOTE.

This report will be open for discussion at a future meeting which will be announced later. All members having information pertaining to this subject, who are not able to attend this meeting, are urged to send it to the Editor for publication.